BANGLADESH

TECHNOLOGY NEEDS ASSESSMENT AND TECHNOLOGY ACTION PLANS FOR CLIMATE CHANGE MITIGATION

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FOREWORD

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) identifies Bangladesh as one of the worst victims of climate change, although it is one of the lowest per-capita emitters historically and currently.

In addressing climate change, Bangladesh has prepared national policies and strategies to make its major development sectors climate-resilient and also to mitigate green house gas mitigation from the potential sectors. For example, the 'Bangladesh Climate Change Strategy and Action Plan-BCCCSAP-2009' identified a number of mitigation measures for short and medium term implementation.

Though it is not obligatory for Bangladesh to reduce emission of green house gas and undertake the low carbon development path but the country is committed to do so, provided the process does not put additional burden on its already overstressed economy and financial capacity and is a win-win option for it with assured adequate international support. Already, dialogues are on internally in Bangladesh with stakeholders for evolving a "green development" concept that promotes a "green economy" and provides "green jobs" in the future. But it has to be in the context of Bangladesh's priorities for accelerating economic growth, poverty reduction, social emancipation and sustainable development.

Undertaking of low carbon development measures, especially ensuring energy efficiency and promoting renewable energy, also have positive impact on the national economy as it will reduce import cost of primary energy. While technology is important from emission reduction but technology, alone, is insufficient. The enabling environment is needed, including having the right policies in place that create the right incentives.

I found the sectors and projects that have prioritized in TNA Bangladesh mitigation report quite resemble the sectors and projects emphasized in the BCCCSAP. I strongly believe that the implementation of mitigation projects prioritized at the TNA Mitigation report will contribute to the global effort of green house gas mitigation.

I thank TNA National Team, my colleagues in the Ministry, experts of the relevant sectors for their invaluable contribution in the development of this report. I sincerely acknowledge the contribution of the project personnel and experts of UNEP, GEF, UNEP RISO Center and AIT for their relentless effort in the implementation of TNA project and come-up with some specific and prioritized measures for climate change mitigation in Bangladesh.

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PREFACE

There are two broad areas of policy action, globally as well as nationally, to face climate change: one is mitigation which calls for actions to lower and ultimately stop the emission of green house gases into the atmosphere and the other one is adaptation which relates to minimization of the adverse impacts of climate change and associated vulnerabilities.

Within this overall climate change context, both mitigation and mitigation involve use of technology and its management (development, transfer, adaptation, adoption and diffusion) along with other related aspects such as financing. In the global context, technology development and transfer has increasingly gained a centre stage in the agenda of negotiations. While in the country context, technology needs assessments (TNA) become as an important management tool for a country in formulating development strategies as well as to identify nationally appropriate mitigation actions (NAMAs).

Bangladesh, being one of the most vulnerable countries to climate change and though its contribution to the generation of green house gas is miniscule, the country wishes to play its part in reducing emission now and the future.

Bangladesh Climate Change Strategy and action Plan 2009 emphasizes 'Mitigation and low carbon development' and identified a series of activities to reduce Bangladesh's carbon emission, now and in the future, including inter alia: a) development of a strategic energy plan and investment portfolio to ensure national energy security and lower greenhouse gas emissions and b) Seek the transfer of state of the art technologies from developed countries to ensure that Bangladesh follows a low-carbon growth path.

In line with the Climate Change Strategy and Action Plan, Bangladesh, with the assistance of UNEP, undertook Technology Needs Assessment (TNA) project to identify the needs for new equipment, techniques, practical knowledge and skills, which are necessary to mitigate GHG emissions and to undertake low carbon development path.

Briefly, this project aims to produce Technology Needs Assessment (TNA) and Technology Action Plans (TAP) for climate change mitigation in Bangladesh. This report provides a list of prioritized the sectors that have potentials for the mitigation of GHG emission. This report also identified a number of mitigation technologies for the sectors having GHG mitigation potentials.

TNA process in Bangladesh followed participatory analysis and consultation with the sector specific relevant experts and stakeholders. I thank all of colleagues, experts and stakeholders who were involved in TNA and contributed in this report.

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ACKNOWLEDGMENTS

Technology Needs Assessments Report, Part I is an outcome of efforts of a number of people, who shared their experiences and views on the impacts of climate change in important development sectors. Furthermore discussed number of technological options GHG mitigation potentials of country's energy and non-energy sectors.

Special acknowledgement is to due to the members of National TNA Team namely Dr Rezaul Karim, Environmentalist and Team Leader of National TNA Team, Dr M Asaduzzaman, Research Director, Bangladesh Institute of Development Studies, Dr Ainun Nishat, Vice Chancellor, BRAC University, Dr Ijaz Hussain, Professor, Bangladesh University of Engineering and Technology, Dr Iqbal Hussain, Assistant Professor, Bangladesh University of Engineering and Technology, Dr. Md Zahurull Haq, Professor, Bangladesh University of Engineering and Technology, Dr AKM Saiful Islam, Associate Professor, Bangladesh University of Engineering and Technology and Mr Md Shamsuddoha of Center for Participatory Research and Development (CPRD).

Acknowledgement is also due to experts and stakeholders of different government and non government organizations, who have participated in the national and local level consultations and provided substantive input throughout the TNA process.

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ABBREVIATIONS

ACT	Advanced Combustion Turbine
ANGCC	Advanced Natural Gas Combined cycle
AIT	Asian Institute of Technology
APC	Advanced Pulverized Coal
BCCSAP	Bangladesh Climate Change Strategy Action Plan
BIDS	Bangladesh Institute of Development Studies
CPRD	Center for Participatory Research and Development
CFL	Compact Fluorescent Lamp
GEF	Global Environment Facility
GHG	Greenhouse Gas
GoB	Government of Bangladesh
HRSG	Heat Recovery Steam Generators
IGCC	Integrated Gasification Combined Cycle
IPR	Intellectual Property Rights
LDC	Least Developed Country
LF	Linear fluorescent lamp
MoEF	Ministry of Environment and Forests
NGCC	Natural Gas Combine Cycle
PPP	Public-private partnership
PSMP	Power Sector Master Plan
SEDA	Sustainable Energy Development Agency
Solar PV	Solar Photovoltaic
TNA	Technology Needs Assessment
TAP	Technology Action Plans
UNEP	United Nations Environment Programme
URC	UNEP RISO Centre

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Part II

Technology Action Plans

Executive Summary

The Part II Report of the Technology Needs Assessments titled 'Technology Action Plan –TAP' aims to identify barriers that could hinder the transfer and diffusion of mitigation technologies as prioritized in the Part I report. Stakeholder consultations are organized to understand types and complexity of barriers to introduce potential mitigation technologies in the country. Bangladesh is committed to follow the low carbon development path to ensure sustainable development in one hand and reducing climate vulnerability on the other hand. Having no obligation, under the UNFCCC, to provide emphasis on the mitigation of GHGs, the Bangladesh Climate Change Strategy and Action Plan is identified mitigation action as one of the thematic areas of the strategy. Bangladesh, as one of the most climate vulnerable countries, explores all potential mitigation technologies to ensure energy security following cleaner path and to reduce climate vulnerability in the long run. However, while conducting the technology need assessment consultations, stakeholders recommended to consider as many as available technologies in this sector and the following mitigation technologies have been given priority: A) Advanced Gas Combustion Turbine, B) Natural Gas Combined Cycle, C) Advanced Generation Natural Gas Combined Cycle, D) Advanced Pulverized Coal (single unit), E) Advanced Pulverized Coal (double unit), F) Single Unit Integrated Gasification Combined Cycle, G) Double Unit Integrated Gasification Combined Cycle, H) Solar Photovoltaic, I) Linear Fluorescent Lamp and J) Compact Fluorescent Lamp. These prioritized technologies have advantage of ensuring energy security within the context of mitigation effort under low carbon path of development. This report elaborated characteristics of these technologies, such as Advanced Gas Combustion Turbines for power generation are mostly heavy-frame machines in a simple cycle configuration around 170-190 MW for the high firing temperatures (approx. 1250^{o}C) of the "F-class" machines. Efficiencies are 36%-38% in simple cycles. In combined cycles, the units are 260-380 MW in size and 53%-56% efficient. Natural Gas Combined Cycle is a gas turbine unit exhausting into a heat recovery steam generator (HRSG) that supplies steam to a steam turbine cycle is the most efficient combined cycle power generation system generating electricity today. Advanced Generation Natural Gas Combined Cycle is a Conventional NGCC technology utilizes two natural gas-fueled F-class CTs and associated electric generators, two supplemental-fired heat recovery steam generators ("HRSG"), and one condensing ST and associated electric generator operating in combined-cycle mode. Advanced Pulverized Coal (single unit) technologies are referred to as "clean coal technologies" and described by a family of pre-combustion, combustion–conversion, and post-combustion technologies. They are designed to provide the coal user with added technical capabilities and flexibility to generate power. Advanced Pulverized Coal (double unit) facility is provided for a nominally 650 MW coal-fired supercritical steam-electric generating unit which employs a supercritical Rankine power cycle in which coal is burned to produce steam in a boiler, which is used to run a ST to produce electric power. Single Unit Integrated Gasification Combined Cycle (IGCC) technology makes possible the utilization of low cost coal and opportunity fuels, such as petroleum coke, residual oil and biomass, for clean efficient and cost effective electricity generation. Recent increases in natural gas prices and concerns about its availability, as well as significant advances in air separation, gasification and syngas cleanup technologies, have made coal and opportunity fuels based Integrated Gasification Combined Cycle (IGCC) plants a competitive option for efficient and environmentally safe power generation compared to direct fired pulverized coal plants and natural gas fired combined cycle (CC) plants. The Double Unit Single Unit IGCC power plant is basically a dual unit of the single unit IGCC plant. Double Unit IGCC is a new power generation system, consisting of a gassifier which gassifies coal to

CO and H2 and separates ash from coal. It has a potential of higher than 50% net thermal efficiency with increased gas turbine combustion temperature, as this has already been realized with natural gas fired combined cycle power plants. It will also result in a 20% reduction of CO_2 while generating the same amount of electricity using coal. Solar Photovoltaic technology, renewable method of power generation, has very good potential to generate electricity, as the country endow with plenty of sun light throughout the year. Solar panel is made up of the natural element silicon, which becomes charged electrically when subjected to sunlight. Sunlight is composed of packets of energy called photons. These photons contain various amounts of energy corresponding to the different wavelengths of light. The solar cell is made up of a material with well-defined possible energy levels for electrons. When a photon is absorbed in the active material, the energy of the photon is transferred to an electron, which becomes excited from a low to a higher energy level. The typical Linear Fluorescent Lamp comprises a cylindrical glass tube sealed at both ends and containing a mixture of an inert gas, generally argon, and *low-pressure* mercury vapor. The nominal lumen capacity, relative efficiency and life lengths are 55-85 per watt, 65% and up to 24000 hours depending on particular designs. The lowest life is 7500 hours which provides economic benefit to users. Compact Fluorescent Lamp is a new technology with a history of about 40 years and new developments for bettering its performance is continuing. It uses the same basic features as for the LFLs but introducing design and other changes. A CFL of 23 W produce the same light as an incandescent bulb of 100 W i.e., a CFL uses 75% less power than an incandescent lamp to produce the same lumen.

In the barrier analysis, the nature of the individual barriers and relationships between barriers are discussed. Furthermore, important barriers are determined and discussed ways to remove barriers. Discussion on barrier identification and analysis are based on economic and non-economic aspects of technology transfer and diffusion. This report highlighted technology characteristics, country specific applicability, status of use, specific barriers, benefits economic, social and environmental development, capital, operational and maintenance costs of individual prioritized technology. The report identified measures for developing enabling framework e.g. overcoming of economic, legal, institutional barriers and different support services like finance, quality services, standard management etc. This report also included market mappings and enabling framework respectively for the technologies which are classified as consumer and capital goods.

This report also includes a project idea i.e. ‘Installation of 1300 MW capacity Advanced Pulverized Coal (Double Unit) plant. Major objective of Advanced Pulverized Coal (Double Unit) project is to increase power supply that in turn will contribute to the country’s growth and development.

This report has been prepared through a consultative process with the involvement of stakeholders from government and non-government organizations of the relevant sectors and technologies. In the consultation process, stakeholders from a wider sector and also from the grassroots level were involved in identifying barriers in transfer and diffusion of technologies, identifying measures to overcome the barriers, development of market maps for enabling framework for the respective technology.

The overall problems and barriers identified in barrier analysis are common in many cases; just a few are specific for certain technology. Considering common and diverse nature of barriers in technology diffusion and transfers, the barriers have been classified into three major aspects: these are economic, technological and maintenance and support services.

The major barriers discussed so far are the high advanced technologies and capacity gaps in operation and management of these technologies. Effective, innovative ways are needed to generate funds from international mechanisms and also thorough public-private partnerships. International cooperation is also required for capacity development and solving the IPR issues.

Although many policies for GHG emission reduction exist in Bangladesh, most of these policies have not been implemented because of lack of funds, shortage of trained manpower, management deficiencies, and rules/regulations of public procurement policy which does not allow the purchase of the best technology. Therefore, it would be worth reviewing the Private Sector Master Plan of power sector and country's foreign direct investment (FDI) policy to encourage more private investment in the power generation sector.

Introduction and diffusion of identified technologies in mitigation, through country-led need assessment, elaborated in the Technology Action Plan (TAP) must be supported by finance and capacity building within and outside the UNFCCC process to remove all kind of barriers.

Institutional arrangement for the TAP and the stakeholders' involvement

Technology Action Plan (TAP) aim at analyzing barriers and enabling framework conditions for the transfer and diffusion of the prioritized technologies in the light of countries' immediate and long-term adaptation planning. TAP is likely to identify possible barriers for each of the prioritized technology and to identify measures to overcome barriers and finally to develop short-, medium- and long-term action plan including the agencies to be involved for transfer and diffusion of the technology.

On the basis of the methodologies of barriers analysis (Ref: TAP Guide book), the National Team undertook a series of stakeholders' consultation to identify the nature of different barriers, relationships between barriers, determine important barriers and find ways to remove barriers.

Prioritized technologies
TNA Report I

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Analyzing the Barriers
Organizing the process
Identifying all possible barriers
Screening all possible barriers to find the key ones
Establishing hierarchy of barriers
Analyzing causal relations

↓

Finding Solutions/ Enabling Framework
Translating barriers into measures
Assessing measures
Group measures

Figure 1: The overall methodologies of barriers analysis and identifying measures for enabling framework

Stakeholder consultation is the main feature TAP preparation. Stakeholders ranged from sectoral experts and professionals from different educational and research institutions government ministries, department and agencies, and NGOs.

Prior to the barrier analysis, the types of barriers are categorized to give more on those. The different categories of barriers are presented in the following box 1:

BOX 1: Categories of barriers

The barriers may first be sub-divided into economic and financial barriers and non-economic/financial ones. The non-financial barriers may be sub-categorised into several more as shown below.

Economic and financial: lack of access to finance, high cost of capital, high O&M costs, low Benefit-cost ratio or internal rate of return,

Non-economic or non-financial barriers may include the following:

Market imperfections and failures: poor market infrastructure, uneven playing field, inadequate sources of increasing returns, barriers to entry, prices not reflecting all costs

Policy, legal and regulatory: inadequate policy, legal and regulatory framework, wide and strict regulatory mechanisms, conflicts of interests, political instability, lengthy bureaucratic procedures rent-seeking by regulators

Network failures: weak linkages among various stakeholders

When all conceivable barriers are identified, the barriers are screened according to their significance. At this stage barriers are categorized into a) essential barriers, i.e., barriers which definitely need to be addressed for technology transfer and diffusion to occur, and b) the non-essential barriers, which arise due to the essential barriers or interactions among them and thus can be discarded and subsequently ignored, provided the essential ones have been resolved.

Measures for developing enabling framework e.g. overcoming of economic, legal, institutional barriers are discussed and are based on expert judgments and stakeholder consultations. The need for different types of support services for overcoming the barriers like finance, quality of services, standard management etc were also discussed in the consultations.

In the process of barrier identification, market mappings have been utilized but only for a few technologies which are classified as either consumer (such as CFL and LDL) or capital goods (solar home systems based on PV). These are shown in Annex II, for other power generation technologies based on natural gas or coal, practically the whole of them have to be or are imported. The market chains of these technologies embodied in specific capital goods is practically almost entirely outside the country. Then again most, if not all, are expected to be implemented through the public sector, as public-private partnership or private sector joint ventures between domestic and foreign private sector firms. Market mappings in none of these cases are of much relevance. But that does not mean that there are no barriers. There are aplenty and these are discussed below. The detail of market map is presented in Annex 2.

Chapter 1. Power Generation and Use Sector

To complement to the country's development priority e.g. attaining sustainable development through green growth and attaining energy security the **power generation and use** will be requiring technological support that will contribute to the reduction of GHG emission.

From the sector prioritization exercise, two subsectors of power sector e.g. power generation and power uses have prioritized for GHG mitigation. Under these subsectors a number of technological measures have been discussed in the stakeholder consultations, and shortlisted the following technologies presented in Table 1.

Table 1: Prioritized technologies for climate change mitigation for power generation and use sector

Power supply	**Category**	**Technology**	**Scale**	**Availability**
Power generation	Gas-based	Advanced combustion turbine	Large	Short term
		Natural gas combined cycle	Large	Already in use; up-scaling needed
		Advanced natural gas combined cycle	Large	Short to medium term
	Coal-based	Single Unit APC	Large	Short to medium term
		Double Unit APC	Large	Short to medium term
		Single unit IGCC	Large	Medium term
		Double unit IGCC	Large	Medium term
	Solar	Solar Home PV	Small	Already in use
Power use	Domestic Lighting	Linear fluorescent lamp (LF)	Large	Already in use
		Compact fluorescent lamp (CFL)	Large scale	Already in use

On the basis of overall weighted score, the technology options are prioritized and ranked from high priority to low priority order and presented in table 2

Table 2: Mitigation technologies for power generation sector as per priority order

Technology	Weighted score		Priority order
	Without PV	With PV	
Natural gas combined cycle	78.91	76.63	1
Solar home PV	75.61		2
Advanced combustion turbine	76.19	74.87	3
Advanced natural gas combined cycle	76.06	74.62	4
Integrated Gasification Combined Cycle (IGCC) Single unit	69.03	68.60	5
Integrated Gasification Combined Cycle (IGCC)	69.03	67.45	6

Double unit			
Advanced Pulverized Coal (APC), Single Unit	68.69	67.91	7
Advanced Pulverized Coal (APC), Double Unit	66.31	66.07	8

Note: 1. 2. PV: Photovoltaics

The solar PV technology in Bangladesh is for dissemination in basically off-grid areas. Hence, the analysis has been done in two parts, i.e with PV which provides an aggregate picture and without PV which is the more operational one at the moment as all power sector projects are basically for expansion of the grid-area and increased supply in the grid-area.

Table 3: Mitigation technologies for power use sector as per priority order

Technology	Weighted score	Priority order
Compact fluorescent lamp (CFL)	68.6	1
Linear fluorescent lamp (LF)	62.1	2

In this exercise an attempt is made to further refine the analysis in terms of first steps in implementation of the acquisition of the prioritized technology. This involves analysis of barriers against such acquisition as well as some ideas regarding the feasibility of the implementation of the establishment of power plants with the identified technologies. The issues of feasibility have both technical and economic aspects and are rather involved exercises and are not possible at this stage of resource and time availability. At the same time, this is also true that some though not all, of the prioritized technology are already under practice and thus would necessitate actually evaluation of performance underground conditions which is even more of an involved exercise.

1.1 Preliminary targets for technology transfer and diffusion based on Section I

Under a sustainable development framework, the Government of Bangladesh emphasizes on green growth, efficiency improvement of the energy sector etc. that will lead to reduced GHG emission. This has been already included in the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) and also to the country's long-term development vision and planning.

The Bangladesh Climate Change Strategy Action Plan (BCCSAP), a 10-year programme to build the capacity and resilience, emphasizes undertaking of low carbon development path. BCCSAP underscores:

- Develop a strategic energy plan and investment portfolio to ensure national energy security and lower greenhouse gas emissions
- Seek the transfer of state-of the art technologies from developed countries to ensure that we follow a low-carbon growth path (e.g., solar, biogas and other technologies)
- Review energy and technology policies and incentives and revise these, where necessary, to promote efficient production, consumption, distribution and use of energy

What is of significance here is that it is not possible at this stage to state the preliminary targets for the prioritized technology although as indicated earlier some are already under consideration although some such as a nuclear power plant is not under our prioritization. A MoU has been signed with a donor country for establishment of such a plant, but the details of the technology, nor its economic feasibility are yet public knowledge. The Government, purportedly, has gone for this plant because of the huge unmet demand for power. In this report, a brief summary of the power plant construction plan between 2012 and 2016 by the government has been provided.

The plan shows that many of the gas fired plants to be established are designed as full-fledged combined cycle plants and thus conforms to our ideas of prioritization. Apparently, quite a few of them are currently constructing the single cycle units; the combined cycle units may be added later. Quite a few coal-fired plants are expected to be constructed within this period but their characteristics are unknown. On the other hand, while solar photovoltaic have progressed very well in the country (nearly 2 million set up so far), the other solar power generation technology is also under the plan, although on a much modest scale. The most disconcerting issue here however is that (i) a nuclear plant is expected to be established, the technical specifications of which are still unknown while (ii) a lot of small rental power plants using various types of oil are being set up which basically employs one of the least efficient technology i.e. reciprocating engines. Thus, getting back to gas and coal probably is what we should stress at the moment rather than specific targets under each except that the designed combined cycle plants which have at the moment provisions for single cycle units must first be converted into full-fledged combined cycle plants. Then again, several (5/6) coal fired plants are in pipeline. However, the technical specifications are unknown except perhaps one with the highest-rated capacity of 1300 MW which is anecdotally known to employ supercritical technology. The rest perhaps will be conventional. In that case, these may be reviewed and be transformed into at least advanced pulverized coal plants whether single or double units if IGCC seems too expensive or not a fully mature technology.

1.2 Barrier analysis

The barrier analysis for the transfer and diffusion of the prioritized technologies has been done through stakeholder consultations. In the stakeholder consultations, the group of experts have discussed and exchanged information on different barriers that would hinder diffusion of technologies, categorized as capital goods. Market mapping also has been done in the stakeholders consultation for the technologies categorized as consumer goods. In the market mapping exercise the stakeholders have discussed the entire existing market elements related to the technologies and the linkages between them. The main elements that have been considered in market mapping are;

a) Enabling environment (e.g. legal, institutional and organizational etc.)
b) Mapping of the market players (e.g. manufacturer, wholesaler, retailer, consumer etc)
c) Support services required for technology transfer and diffusion (e.g. finance, technology standard, performance, product warranty, quality management etc.)

On the basis of information gathered from the stakeholder consultation and market mapping, the steering committee and group of experts have categorized the barriers into financial and non-financial categories.

1.2.1 Barrier analysis for the transfer and diffusion of Natural Gas Combine Cycle (NGCC) technology

a) Financial barriers

- NGCC is a costly technology. Capital costs for a typical plant size of 540 MW may come US$ 500-600. This was an 2010 estimate and may have gone up further to date. Fixed O&M costs are also high although the variable O&M costs are low.
- Funding may not be easily available, as private sector foreign direct investment is not allowed at the moment while joint ventures are mostly for small to medium sized plants, not such big ones. Note that the 2012-16 power generation plan has several NGCC mentioned but for the time being apparently only single cycle units are in the pipe-line. This may actually raise the price tag as and when the combined cycle part is retro-fitted.
- All capital equipments are imported and therefore a speedy expansion will create a heavy burden on the balance of payments creating other macroeconomic pressures.

b) Non Financial barriers

- **Problem of primary fuel availability:** There is a dearth of primary fuel, particularly natural gas which also has alternative strategic uses such as for manufacture of nitrogenous fertilizer critical for ensuring food security. The present known reserve will begin dwindle by 2020 or soon thereafter. Hence, a decision for fully gas-based plants may need to be taken with caution particularly as power plants have a rather long life, certainly many years beyond 2020.
- **Legal barriers:** Combined cycle plants are well-known; but specific components innovated more recently may have IPR which may also make it more costly if the license has to be purchased
- **Institutional and human capacity problem:** Although the country has some experience of NGCC, the human capacity to technologically manage large, modern generation units with recently innovated components is limited because of lack of sufficiently skilled manpower. Furthermore, if such a plant is set up it is almost likely to be in the public sector and managed through Bangladesh Power Development Board which has a rather poor compensation and incentives system to attract sufficiently skilled people for the job.

  As stated above the short term plan of 2012-16 is already deficient in terms of planning for NGCC; the Power Sector Master Plan (updated) is also deficient in that it does not provide enough of attention to NGCC and therefore needs to be revised as a guideline for action

1.2.2 Barrier analysis for the transfer and diffusion of solar home PV technology

a) Financial barriers

- Solar home PV has spread rather fast in the country and nearly 2 mn have been installed. But prices are still high for poor customers for which reason a good measure of subsidy is provided although to whom the subsidy actually goes, on-the-ground partner organizations (PO) who actually sell these generally on credit or the households remain an issue.
- Costs are high because the rate of interest charged and the repayment period for households are higher and shorter respectively than the rates paid by the POs over a doubly longer period.
- Costs go up much more if clients wish and they do in many cases for higher capacity systems (the most popular previously had been 40-50 Wp, but now increasingly shifted to 20-40 Wp) which are needed for meeting various demands for energy services beyond basic lighting.
- Solar panels are all imported and mainly from China because it is cheaper (though possibly technically not the best) but nevertheless creates a demand for import using scarce foreign exchange. A speedy expansion will mean increasing the balance of payments pressure.

b) Non Financial barriers

- **Market barrier:** Only off-grid areas are expected to be under solar home system, but apparently there is unmet demand also in grid-based areas; present policy does not allow grid-based areas to be under present solar home expansion plan

  While recent research indicates that there is a market for nearly 20 million solar homes in the present off-grid areas, the grid-based area will certainly expand over time making the future uncertain for the POs in the medium term future and they may not wish to be as aggressive as before particularly as there are now talks of lowering the subsidy or grants in which case, the interest rate charged to households will almost triple in the extreme case making solar home systems even more costly than now.
- **Technological**: Few major technological problem exists; but updating of technology (particularly involving batteries) needed for catering to higher demand in existing and future connected homes;
- **Environmental:** Batteries pose problems as this is the costliest part and also because of the problem of disposal as roughly half of the batteries are never returned and possibly disposed of in environmentally unsafe manner.
- **Institutional and human capacity:** The country so far had been able to expand the solar home system rather fast but is already stretching the institutional capacity of the main institutional vehicle, the Infrastructure Development Company Limited (IDCOL). Instead of a monopoly sponsor, a market-based competitive and well-regulated system should develop. But lack of enough skilled human capacity as well as proper regulatory framework is withholding such market-based expansion.

1.2.3 Barrier analysis for the transfer and diffusion of Advanced Combustion Turbine Technology

a) Financial barriers

- Costly technology. Fixed O&M costs are also high although the variable O&M costs are low.
- Funding may not be easily available, as private sector foreign direct investment is not allowed at the moment while joint ventures are mostly for small to medium sized plants, not such big ones.
- All capital equipments are imported and therefore a speedy expansion will create a heavy burden on the balance of payments creating other macroeconomic pressures.

For this type of plant, the problems are rather similar to those for an NGCC plant except that the costs are somewhat less in terms of capital investment with consequent less pressure on the exchequer and the balance of payments. But there may be other technical problems and consequent institutional capacity difficulties as described under.

b) Non Financial barriers

- **Technological:** The ACT has many variants; the F-class has been considered here as this the most proven technology, but others developed over time and still developing may be more efficient but not yet completely proven; For all versions, particularly the latter versions IPR may be a problem to implement;
- **Institutional and human skill:** Technological and managerial capacity to run such plants is limited and may be practically non-existent.

1.2.4 Barrier analysis for the transfer and diffusion of Advanced Natural Gas Combined cycle (ANGCC) technology

a) Financial barriers

- Costly technology. Fixed O&M costs are also high although the variable O&M costs are low.
- Funding may not be easily available, as private sector foreign direct investment is not allowed at the moment while joint ventures are mostly for small to medium sized plants, not such big ones.
- All capital equipments are imported and therefore a speedy expansion will create a heavy burden on the balance of payments creating other macroeconomic pressures.

b) Non Financial barriers

- **Technological:** little or no experience of ANGCC and thus the legal (particularly IPR), institutional, human capacity and skill issues become more critical than in other cases.

  Also note that as the country has no experience of ANGCC, it would be better to attract foreign direct investment for such plants, yet investors may be deterred if natural gas availability is not ensured in the longer term they may be deterred

1.2.5 Barrier analysis for the transfer and diffusion of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology

a) Financial barriers

- IGCCs are very costly – US$ 2-4 bn - depending on whether single or double units; O&M costs are also high; it is thus very difficult to mobilize such level of resources particularly when the technology or parts of it is protected by IPR and foreign direct private investment is discouraged while even in case of joint ventures, there is likely to be no domestic taker
- The technology will have to be imported and given the very high cost, will create high balance of payments pressure and consequent macroeconomic problems (e.g., inflationary pressure). Furthermore if the coal has to be imported because of the lack of clear coal policy on extraction methods, this may raise the balance of payments problems further as well as the variable costs as imported coal from many places has sulphur which needs to be cleaned after gasification
- The setting of the plant will be determined partly by availability of infrastructure and partly whether it is imported or domestic coal is to be used. If domestic coal is used for mine-mouth generation or imported coal for near the port generation, additional infrastructure will have to be built and maintained, a rather costly affair. Furthermore particularly for imported coal huge storage spaces for coal may be needed to ensure smooth supply to the plant, again a costly endeavor
- As there are few such plants in the world, it may be imported only from very few vendors which may lead to monopoly pricing and higher than normal cost

b) Non Financial barriers

Technological problems

- IGCC is a new technology and there are few countries which have tried it yet and thus may not be fully proven
- There are major IPR problems with the technology or parts of it
- The problems of future availability of coal for gasification may arise as the present coal policy regarding extraction method may not ensure future supply of domestic coal which is more or less free of sulphur while other imported coal, particularly from India, which appears to be the preferred source due to transport costs, contain sulphur and thus the technology has to be integrated with cleaning of the coal gas, a rather complex process

Institutional and human capacity problems

- The Power Sector Master Plan (updated) has scant mention of this technology and thus need to be revised if this technology is preferred,. This is however unlikely in the recent future as the Power Sector Masterplan has only been recently updated.
- Very few countries have some experience of the mentioned technology and to known date Bangladesh has none. Hence the institutional and human capacity to technologically manage such very large, modern generation units is practically non-existent in the country.

1.2.6 Barrier analysis for the transfer and diffusion of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology

a) Financial barriers

- Costly technology. Fixed O&M costs are also high although the variable O&M costs are low.
- Funding may not be easily available, as private sector foreign direct investment is not allowed at the moment while joint ventures are mostly for small to medium sized plants, not such big ones.
- All capital equipments are imported and therefore a speedy expansion will create a heavy burden on the balance of payments creating other macroeconomic pressures.

b) Non Financial barriers

Technological problems

- APC is a new technology and there are few countries which have tried it yet and thus may not be fully proven
- There are major IPR problems with the technology or parts of it
- The problems of future availability of coal for gasification may arise as the present coal policy regarding extraction method may not ensure future supply of domestic coal which is more or less free of sulphur while other imported coal, particularly from India, which appears to be the preferred source due to transport costs, contain sulphur and thus the technology has to be integrated with cleaning of the coal gas, a rather complex process

Institutional and human capacity problems

- The Power Sector Master Plan (updated) has scant mention of this technology and thus need to be revised if this technology is preferred. This is however unlikely in the recent future as the Power Sector Masterplan has only been recently updated.
- Capacity to technologically manage such very large, modern generation unit is practically non-existent and so is the experience particularly of super critical coal plants few countries have some experience of the technology and Bangladesh has none. Hence, the institutional and human capacity to technologically manage such very large, modern generation unit is practically non-existent in the country.
- Apparently, a new plant is to to be built near a port city with imported coal is a double unit APC of 1300 MW capacity. It must be noted that providing a secure supply chain becomes extremely important and that includes regular dredging of the port for maintaining the draught for large vessels to anchor, long-term supply contracts, and other necessary infrastructure.

1.2.7 Barrier analysis for the transfer and diffusion of Compact Fluorescent Lamp (CFL) and Linear Fluorescent lamp (LF)

CFL and linear FL as these are proven technologies but both are costlier than the normal incandescent bulbs, the CFL are more so despite the lower long-term cost due to long life and also the better quality of light. Yet, the energy-saving lamps (the other local name for

CFL) are becoming increasingly quite ubiquitous. One thus can discern two types of barriers, which are in a sense the two sides of the same coin.

a) Financial barriers

- Higher cost of purchase compared to incandescent lamps
- The related (though one-time) higher costs of fixtures compared to incandescent lamps

b) Non Financial barriers

- **Institutional/regulatory issues:** Lack of proper regulatory mechanism for quality control of CFL and LFs and thus the easy availability of the substandard lamps. This causes replacement to be more frequent and thus on the whole even costlier to the consumer.
- **Environmental issues:** Lack of proper disposal facilities for fused lamps pose environmental health hazards. Nobody has any idea of where these ultimately end up and how hazardous these waste products are.

1.2. 8 Linkages of the barriers identified

The overall problems and nature of barriers identified in barrier analysis are common in many cases; just a few are specific for a certain technology. There are two types of issues that arise here. Firstly, the nature of commonality and secondly, how the barriers might be linked with each other across technologies within and between specific groups of technology within the same sector.

On the nature of commonality, note that for most prioritized technologies for power generation the cost of capital machineries is rather high for two apparent reasons; first, the protection of the technologies or their specific elements due to IPR and second in most cases due to the frontier nature of the technology. Some such as the IGCC is a case in point The number of suppliers as well as practitioners the world wide except in a few cases such as NGCC are not many and that gives them a kind of power for market (read price) manipulation.

The other problem relates to the issue of supply of primary fuel within a given fuel-based technology. For all the gas-based technologies, this is a major problem due to shortage of supply from domestic sources. In case of coal also, there is a problem of supply from domestic sources for entirely different type of reason but the outcome is similar.

The third commonality is that the present updated Power Sector Master Plan is not much forward looking and thus needs to be revised to take into account the upcoming mature and nearly mature and efficient technologies. Without this revision, much of the forward-looking solutions to the twin problems of lowering carbon emission while satisfying development needs for energy may not be resolved.

Note must be taken that the usual problems of institutional and limited human skills are not mentioned again because technicalities between the technologies even within the specific fuel-based ones are quite different. Thus, a person well-acquainted with NGCC may well understand the principles of IGCC but needs to be retrained to run an IGCC plant even if he/she has experiences of an NGCC.

But this may not be the case in case of all types of technology. For example, for water sector there may be quite a few overlaps across technologies as shown in Table 4.

Table 4: Summary of common barriers of water sector technologies

Types of Barrier	Common Barriers
Economic Barriers	Lack of investment, incentive policies
	Higher initial cost
Technological Barriers	Insufficient technology information and technical assistance
	Lack of technical expertise and capacity
Capacity, Maintenance and Support Services	Lack of skilled personnel
	Limited installation and maintenance capacity
	Lack of collaboration and networking among the organizations

1.3 Enabling framework for overcoming the barriers

Having the list of identified barriers and thorough understanding of the barriers, the TNA National Team has examined the ways to overcome the barriers. In doing so, measures in each category of barriers are presented in the following box 2;

BOX 2: Measures to address barriers

- Measures to address economic and financial barriers
- Measures to address market failures
- Measures to address policy, legal and regulatory related barriers
- Measures to prevent network failures
- Measures to increase institutional and organizational capacity
- Measures to improve human skills
- Measures to address social, cultural and behavioral barriers
- Measures to increase information and awareness
- Measures to address technical barriers
- Measures to address other barriers

Policies and strategies:	Enabling policies and measures are important to promote technology transfer.
Education and Training:	Education and training are required for capability building of the technical experts, extension workers and others for technology promotion, ensuring support services and proper maintenance of the deployed technologies
Technology Demonstration:	Technology demonstration and awareness-rising to overcome social barriers.
Market support system:	Incentives and tax, tariff and non-tariff barriers etc.

International Cooperation:	The national authority may not be competent enough to develop and diffuse updated technology which is why networking and cooperation with the international organizations are required.
IPR Issues:	In relation to some technologies international trade and IPR may hamper technology transfer; other regional trade agreement also may act barriers, which should be address through international cooperation.

Considering the above factors, measures to overcome barriers of technology diffusion and transfer of power generation and use sector are presented below. Note that the measures include several which were raised by the stakeholders in the workshop.

1.3.1 Possible solutions to address the barriers for the transfer and diffusion of Natural Gas Combine Cycle (NGCC) technology

The economic and financial barriers basically are the high cost of acquisition of technology as well as high fixed O&M costs. Two types of measures may be adopted, how to lower the cost and second how to generate the funding. While this issue has not been investigated in any detail, Bangladesh Power Development Board (PDB), the public sector apex body for electricity generation, as well as coordination of transmission and distribution has huge operating losses of more than Taka 41 billion (or around US$ 500 mn) and thus PBD is not in condition to generate funds on its own from any major capital investment.

Furthermore, the BPDB has to pay various taxes on all its imports. Private sector foreign firms are exempted from many of these. This indicates that the best bet is to have joint ventures in which case, the major initial capital costs are borne by the foreign firms and the various local preparatory costs are borne by the domestic private investor. As both face similar fiscal rules for payments of import taxes, the equipments may be imported under either. This way, while the generation of resources will be easier, the costs of operation will also be less than if it is wholly under BPDB. This applies to all power generation plants to be established for generation with gas or coal.

The more important question is whether this will be enough for really large plants. An alternative is to tap the resources of multilateral banks such as ADB which has in the recent past helped set up several new public sector generation facilities. Also, additional fiscal benefits may be offered for larger plants under private initiative and for faster implementation of projects so that the benefits begin to flow as early as possible. Furthermore, attempts may be made for syndicated bank loans with participation by foreign banks as a prerequisite to ensure foreign investment. Also, if carbon credits can be earned due to higher efficiency, this may also help in easing the burden somewhat.

a) **Measures against fuel availability:** A much more difficult issue is the future availability of primary fuel which may also deter private investors. Higher efficiency will partly compensate for that but two more measures are necessary, both operational over longer term. The first is to import natural gas particularly from Myanmar. Such efforts are on but would necessitate intensive efforts and diplomatic finesse. But more importantly this will also necessitate large investments in pipe line construction as well as long term pricing contracts and payments arrangements

b) **Planning problem**: There is a general problem with the Power Sector Master Plan as indicated earlier. The updating has to be done and the Government will have to take steps for that. The present TAP may help in raising awareness of the policy makers and thus needs to be widely circulated among them

c) **Legal issues – IPR:** The extent of the problem is not clearly known. So the first step should be to find how problematic it is; who own the proprietary rights and how those may be circumvented or resolved. WIPO's help may be sought

d) **Institutional and human skill formation issues:** Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory

1.3.2 Possible solutions to address the barriers for the transfer and diffusion of solar home PV technology

a) **Economic and financial measures:** The present level and terms of subsidies and credit to the partner organization (those disseminating on the ground) and the households are probably just right at the moment. But further up scaling will need to lower costs of purchase to and total payments made by households. Simulations indicate that lowering rates of interest to households purchasing on credit will help but will lower the profits of the partner organizations and thus becomes a disincentive. The best way would be to lower rate of interest to households, earn carbon credits (the present estimated savings of carbon dioxide per year is 240 thousand mt due to solar homes) and use the proceeds to raise grants to POs to compensate for their indicative losses.

Import tariffs, and related taxes may be adjusted for cheaper import of new more efficient components

b) **Measures against market barrier:** The issue needs to be thoroughly reviewed to allow solar PV systems in on-grid areas under certain conditions

c) **Institutional measures:** The problem of single principal-many agents (IDCOL and POs) needs to be reviewed. Indications are that for up–scaling, time has come for opening the market to others under strict regulatory measures, rules and procedures. How this may be done should first be studied well and its feasibility determined clearly.

d) **Technological measures**

- Constant up-gradation of technology through an information-clearing system
- Review battery disposal systems in other countries where this is major problem and suggest measures accordingly; monitor the new regulations that have been put in place recently regarding battery disposal and suggest improvements

1.3.3 Possible solutions to address the barriers for the transfer and diffusion of Advanced Combustion Turbine Technology

a) **Measures against fuel availability:** A much more difficult issue is the future availability of primary fuel which may also deter private investors. Higher efficiency will partly compensate for that but two more measures are necessary, both operational over longer term. The first is to import natural gas particularly from Myanmar. Such efforts are on but would necessitate intensive efforts and diplomatic finesse. But more importantly this will also necessitate large investments in pipe-line construction as well as long-term pricing contracts and payments arrangements.

b) **Planning problem**: There is a general problem with the Power Sector Master Plan as indicated earlier. The updating has to be done and the Government will have to take steps for that. The present TAP may help in raising awareness of the policy makers and thus needs to be widely circulated among them

c) **Legal issues – IPR:** The extent of the problem is not clearly known. So the first step should be to find how problematic it is; who own the proprietary rights and how those may be circumvented or resolved. WIPO's help may be sought

d) **Institutional and human skill formation issues:** Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory

1.3.4 Possible solutions to address the barriers for the transfer and diffusion of Advanced Natural Gas Combined cycle (ANGCC) technology

a) **Measures against fuel availability:** A much more difficult issue is the future availability of primary fuel which may also deter private investors. Higher efficiency will partly compensate for that but two more measures are necessary, both operational over longer term. The first is to import natural gas particularly from Myanmar. Such efforts are on but would necessitate intensive efforts and diplomatic finesse. But more importantly, this will also necessitate large investments in pipe-line construction as well as long-term pricing contracts and payments arrangements.

b) **Planning problem**: There is a general problem with the Power Sector Master Plan as indicated earlier. The updating has to be done and the Government will have to take steps for that. The Present TAP may help in raising awareness of the policy makers and thus needs to be widely circulated among them

c) **Legal issues – IPR:** The extent of the problem is not clearly known. So the first step should be to find how problematic it is; who own the proprietary rights and how those may be circumvented or resolved. WIPO's help may be sought

d) **Institutional and human skill formation issues:** Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory

1.3.5 Possible solutions to address the barriers for the transfer and diffusion of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology

a) **Measures against coal availability:** Unless domestic coal is extracted (possibly not happening in the coming 3-4 years due to various reasons, the absence of a distinctive coal policy being a main one), coal has to be imported. And the coal has to be without Sulphur as otherwise, the costs of desulphurization and associated ones of environmental measures will rise. That means somewhat of a long supply route to Australia or possibly Indonesia as has been reportedly decided in case of the intended 1300 MW APC instead of using Indian coal. That means probably also higher costs, and costlier transports cost rising the over-all cost of operation.

b) **Planning problem**: There is a general problem with the Power Sector Master Plan as indicated earlier. The updating has to be done and the Government will have to take steps for that. In this the Present TAP may help in raising awareness of the policy makers and thus needs to be widely circulated among them

c) **Legal issues – IPR:** The extent of the problem is not clearly known. So the first step should be to find how problematic it is; who own the proprietary rights and how those may be circumvented or resolved. WIPO's help may be sought

d) **Institutional and human skill formation issues:** Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory

e) **Infrastructural measures:** Imported coal from non-Indian sources will also mean that the handling facilities and associated infrastructure improvements will be necessary which are lacking at the moment. This may also mean changes in decisions on the location of plant and associated infrastructure development issues in a different place rather than in the intended one.

1.3.6 Possible solutions to address the barriers for the transfer and diffusion of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology

a) **Measures against coal availability:** Unless domestic coal is extracted (possibly not happening in the coming 3-4 years due to various reasons, the absence of a clear cut coal policy being a main one), coal has to be imported. And the coal has to be without Sulphur as otherwise, the costs of desulphurization and associated ones of environmental measures will rise. That means somewhat of a long supply route to Australia or possibly Indonesia as has been reportedly decided in case of the intended 1300 MW APC, instead of using Indian coal. That means probably also higher costs, and costlier transports cost rising the over-all cost of operation.

b) **Planning problem**: There is a general problem with the Power Sector Master Plan as indicated earlier. The updating has to be done and the Government will have to take steps for that. The Present TAP may help in raising awareness of the policy makers and thus needs to be widely circulated among them

c) **Legal issues – IPR:** The extent of the problem is not clearly known. So the first step should be to find how problematic it is; who own the proprietary rights and how those may be circumvented or resolved. WIPO's help may be sought

d) **Institutional and human skill formation issues:** Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory

e) **Infrastructural measures:** Imported coal from non-Indian sources will also mean that the handling facilities and associated infrastructure improvements will be necessary which are lacking at the moment. This may also mean changes in decisions on the location of plant and associated infrastructure development issues in a different place rather than in the intended one.

1.3.7 Possible solutions to address the barriers for the for the transfer and diffusion of Compact fluorescent lamp (CFL) and Linear fluorescent lamp (LF)

a) **Economic and financial measures:** Fiscal measures may be taken to lower the tax on fully assembled and knocked down parts of the CFL and LFL. For the major domestic industries on these lamps, the raw materials may be allowedat lower tariff. Whereas higher taxes may be imposed on incandescent bulbs to raise their relative prices

b) **Regulatory and standardization measures**

- Strict regulatory and standardization measures should be put in place and enforced regarding quality of the final products and accessories
- A monitoring mechanism should be put in place for understanding the gravity of the problems of outages of lamps due to low quality as well as for disposal of fused lamps. A penalty system for firms marketing low standard lamps or accessories may be considered.

1.3.8 Recommended solutions for Power Generation and Use Sector

There are enormous possibilities to make the power sector less carbon-intensive. Improving power generation efficiency not only will reduce level GHG emission but also will reduce cost of power production in the long run and will help reaching electricity to end users. This in turn could reduce tariffs or, at the least, reduce the inflationary pressure on electricity tariffs. Renewable Energy-based electricity and energy conservation measures, on the other hand, directly reduce CO2 emissions. These also help to reduce the need for fossil fuels whose costs are continually trending upwards.

Improvements in the effectiveness of energy use have a three-fold impact: (i) improving energy security; (ii) reducing costs and (iii) mitigating environmental externalities. Improving energy efficiency — using either the technical or the economic definition — can lead to two different outcomes. First, it can lead to more output or wellbeing being created for each unit of energy used. Secondly, it can lead to less energy being used to create the same amount of output or wellbeing. Either or both of these outcomes will increase the quantum of energy supply and thereby contribute to energy security.

Given the above context the recommended solutions for transfer and diffusion of power generation and use technologies are:

- Public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency; Syndicated loans from a consortium of banks may be tapped
- Encouraging PPP and IPR issue needs to be investigated properly; WIPO's help may be sought
- Encouraging PPP and revising the Power Sector Master Plan (PSMP)
- Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory, particularly for joint or wholly-owned foreign ownership
- Constant up gradation of technology through an information-clearing system ; financial mechanism may need to be tailored accordingly; review battery disposal systems in other countries where this is major problem and suggest measures accordingly; tariffs, taxes may be adjusted for cheaper import of new more efficient components

Beside the above measures, the legal basis for implementing energy efficiency measures for energy conservation should be established by enacting a law on energy by establishing a foundation for GOB regulation in the field of energy use and development of renewable energy (RE). To stimulate the introduction of renewable energy sources in the energy balance of the country, the law may provide tax incentives for investment in renewable energy and exemption from import duties on equipment for renewable energy.

In order to implement productive activities and strategies for energy efficiency, a national body could be established in Bangladesh, which will be responsible for carrying out GoB policy on efficient use of energy resources and energy conservation.

1.4 Technology action plan, project ideas, and other issues in Power Generation and Use Sector

1.4.1 Technology action plan

1.4.1.1 Technology action plan for Natural Gas Combine Cycle (NGCC) technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 5: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Natural Gas Combine Cycle (NGCC) technology	Investment	Making detail cost estimation with the targeted timeline for establishment of Natural Gas Combine Cycle (NGCC) technology	√	

		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
		Organizing syndicated loans from a consortium of banks		√
		Establishing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency		√
	Capacity development	Reviewing technical and institutional capacities of the existing power sector institutions for operation and management of NGCC technology	√	
		Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory	√	
		Developing of a comprehensive action plan for technical and institutional capacity building	√	
	Organizational/ behavioral change	Creating network of experts and among research and other academic institutions to generate updated knowledge on Natural Gas Combine Cycle (NGCC) technology	√	
	Laws/ Policy	Reviewing IPR issue to have free access to the technology and seeking WIPO's help in this regard	√	
		Developing regulatory framework for PPP for Natural Gas Combine Cycle (NGCC) technology installation and management		√

b) Technology Action Plan

Table 6: Technology action plan for Natural Gas Combine Cycle (NGCC) technology

Sector: Power generation					
Specific technology: Natural Gas Combine Cycle (NGCC) technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted timeline for establishment of Natural Gas Combine Cycle (NGCC) technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	Ministry of Power and Mineral Resources (MoPMR), Power Division; Planning and Finance ministry; Private sector; WIPO	2013-2017	60	Readily available detail cost estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2017	40	Communicated technology specific proposal to the development partners and private sector investors
Organizing syndicated loans from a consortium of banks	To generate matching funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	80	Ensured long-term project funding for technology installation on PPP basis
Establishing public-private partnership for resource	To generate immediate and long-term funds from national	Power Division; IDCOL Domestic &	2013-2023	120	Ensured long-term project funding for technology

mobilization as well as earning carbon credits on saved emission due to higher efficiency;	international sources.	foreign private sector companies			installation on PPP basis
Capacity development					
Reviewing technical and institutional capacities of the existing power sector institutions for operation and management of NGCC technology	To identify technical and institutional capacity gaps.	Power Division; private sector; Domestic & foreign private sector companies	2013-2017	80	Identified capacity gap of the respective power sector institutions
Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	120	Power sector Institutions are staffed with skilled and expert human resource
Developing of a comprehensive action plan for technical and institutional capacity building	To help policy makers and other stakeholders to prioritize actions and make investment decision on the priority action.	Power Division; Ministry of Planning	2013-2017	80	Readily available comprehensive action plan for the policy makers and investors
Organizational/ behavioral change					
Creating network of experts and among research and other academic institutions to generate updated knowledge on	To facilitate cooperation and information sharing between institutions and experts	Power Division; Ministry of Science and Technology; private sector; Domestic &	2013-2017	40	Increased sharing of information among experts and institutions.

Natural Gas Combine Cycle (NGCC) technology		foreign private sector companies			
Policy and law					
Reviewing IPR issue to have free access to the technology and seeking WIPO's help in this regard	To have free access to the advanced tools and technologies	Power Division; Planning and Finance ministry; Ministry of Science and Technology; WIPO	2013-2017	50	Removed IPR barriers in accessing modern tools technologies
Developing regulatory framework for PPP for Natural Gas Combine Cycle (NGCC) technology installation and management	To facilitate private sector involvement in power generation sector	MoPMR, Power Division;	2013-2023	70	Developed private sector supportive laws and policies to leverage investment in power generation.

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.2 Technology action plan for solar home PV technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 7: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Solar home PV technology	Investment	Making detail cost estimation with the targeted implementation timeline of Solar home PV technology	√	
		Making technology specific proposal and generating funds	√	

		from the development partners and other international mitigation funding sources		
		Continuing subsidy and credit as given now		√
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of home solar PV technology	√	
		Constant up-gradation of technology through an information-clearing system through private companies producing components at home as well as through IDCOL;		√
		Developing of a comprehensive action plan for technical and institutional capacity building	√	
	Organizational/ behavioral change	Reviewing battery disposal systems in other countries where this is major problem and suggest measures accordingly	√	
		Introducing community/ consumer level capacity development on the maintenance of Solar PV Systems	√	
	Laws/ Policy	Reviewing policy to allow solar PV systems in on-grid areas under certain conditions	√	
		Adjusting tariffs, taxes for cheaper import of new and more efficient components		√

b) Technology Action Plan

Table 8: Technology action plan for solar home PV technology

Sector: Power generation					
Specific technology: Solar home PV technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000	Monitoring, Reporting and verification for measure

				USD)	
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Solar home PV technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Planning and Finance ministry; Private sector;	2013-2017	80	Readily available detail cost estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Planning and Finance ministry;	2013-2017	60	Communicated technology specific proposal to the development partners and private sector investors
Continuing subsidy and credit for market promotion as providing now	To keep product price to the reach of the consumers	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	40	Increased consumer's access to the product at reasonable cost
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of home solar PV technology	To identify technical and institutional capacity gaps.	Power Division; Domestic & foreign private sector companies IDCOL, NGOs who are supplying with license from IDCOL;	2013-2017	80	Identified capacity gap of the respective institutions
Constant up-gradation of technology through an information-clearing system	To ensure quality solar home PV to the consumers level.	Power Division; Domestic & foreign private sector companies	2013-2023	120	Increased availability of more efficient solar home PV

through private companies producing components at home as well as through IDCOL;		IDCOL, NGOs who are supplying with license from IDCOL;			
Developing of a comprehensive action plan for technical and institutional capacity building	To help policy makers and other stakeholders to prioritize actions and make investment decision on the priority action.	Power Division; Domestic & foreign private sector companies IDCOL,	2013-2017	80	Readily available comprehensive action plan for the policy makers and investors
Organizational/ behavioral change					
Reviewing battery disposal systems in other countries where this is major problem and suggest measures accordingly	To find out sustainable and environment friendly ways for battery disposal	Power Division; Domestic & foreign private sector companies IDCOL,	2013-2017	50	Developed a sustainable and environment friendly battery disposal mechanism
Introducing community/ consumer level capacity development on the maintenance of Solar PV Systems	To build technical capacity of the community people in maintenance of Solar PV Systems	Power Division; IDCOL, NGOs who are supplying with license from IDCOL;	2013-2017	100	Increased capacity of local people in the maintenance of Solar PV Systems
Policy and law					
Reviewing policy to allow solar PV systems in on-grid areas under certain conditions	To extend coverage of the solar PV systems in on-grid areas	Power Division; Planning and Finance ministry;	2013-2017	70	Introduced a regulatory framework allowing solar PV systems in on-grid areas
Adjusting tariffs, taxes for cheaper import of new and more efficient components	To keep price of the solar PV systems lower	Power Division; Ministry of Planning, Ministry of Finance	2013-2023	80	Introduced a consumer friendly tariff policy

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.3 Technology action plan for Advanced Combustion Turbine Technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 9: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Advanced Combustion Turbine Technology	Investment	Making detail cost estimation with the targeted implementation timeline of Advanced Combustion Turbine Technology	√	
		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
		Syndicated loans from a consortium of banks		√
		Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;		√
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Advanced Combustion Turbine Technology	√	
		Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory, particularly for joint or wholly-owned foreign ownership	√	

		Developing of a comprehensive action plan for technical and institutional capacity building	√	
	Organizational/ behavioral change	Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	√	
	Laws/ Policy	Reviewing of Power Sector Master Plan to facilitate private investment on power generation	√	
		Solving of IPR issues through international cooperation and coordination.	√	
		Establishing clear institutional framework and policy for PPP		√

b) Technology Action Plan

Table 10: Technology action plan for Advanced Combustion Turbine Technology

Sector: Power generation					
Specific technology: Advanced Combustion Turbine Technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Advanced Combustion Turbine Technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Planning and Finance ministry; Private sector; WIPO	2013-2017	120	Readily available detail const estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international mitigation funding	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Planning and Finance ministry;	2013-2017	80	Communicated technology specific proposal to the development partners and private sector investors

sources					
Organizing syndicated loans from a consortium of banks	To generate matching funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	50	Ensured long-term project funding for technology installation on PPP basis
Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;	To generate immediate and long-term funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	70	Ensured long-term project funding for technology installation on PPP basis
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of home solar PV technology	To identify technical and institutional capacity gaps.	Power Division; private sector; Domestic & foreign private sector companies, NGOs, IDCOL	2013-2017	70	Identified capacity gap of the respective power sector institutions
Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects, training of Bangladeshi personnel must be made mandatory, particularly for joint or wholly owned foreign ownership	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	150	Power sector Institutions are staffed with skilled and expert human resource

Developing of a comprehensive action plan for technical and institutional capacity building	To help policy makers and other stakeholders to prioritize actions and make investment decision on the priority action.	Power Division; Ministry of Planning	2013-2017	80	Readily available comprehensive action plan for the policy makers and investors
Organizational/ behavioral change					
Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	To facilitate cooperation and information sharing between institutions and experts	Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	60	Increased sharing of information among experts and institutions.
Policy and law					
Reviewing of Power Sector Master Plan to facilitate private investment on power generation	To facilitate private sector investment in power generation	Power Division; Ministry Planning and Finance ministry;	2013-2017	80	Developed private sector supportive laws and policies to leverage investment in power generation.
Solving of IPR issues through international cooperation and coordination.	To have free access to the advanced tools and technologies	Power Division; Ministry of Planning, Ministry of Science and Technology; WIPO	2013-2017	100	Removed IPR barriers in accessing modern tools technologies
Establishing clear institutional framework and policy for PPP	To facilitate private sector involvement in power generation sector	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2023	90	Developed private sector supportive institutional framework and policy to leverage investment in power generation.

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.4 Technology action plan for Advanced Natural Gas Combined Cycle (ANGCC) technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 11: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Advanced Combustion Turbine Technology	Investment	Making detail cost estimation with the targeted implementation timeline of Advanced Combustion Turbine Technology	√	
		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
		Syndicated loans from a consortium of banks may be tapped		√
		Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;		√
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Advanced Combustion Turbine Technology	√	
		Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	√	
		Developing of a comprehensive action plan for technical and	√	

		institutional capacity building		
	Organizational/ behavioral change	Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	√	
	Laws/ Policy	Reviewing of Power Sector Master Plan to facilitate private investment on power generation	√	
		Solving of IPR issues through international cooperation and coordination.		
		Establishing clear institutional framework and policy for PPP		

b) Technology Action Plan

Table 12: Technology action plan for Advanced Combustion Turbine Technology

Sector: Power generation					
Specific technology: Advanced Combustion Turbine Technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Advanced Combustion Turbine Technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Planning and Finance ministry; Private sector;	2013-2017	120	Readily available detail const estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international mitigation funding	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2017	70	Communicated technology specific proposal to the development partners and private sector investors

sources					
Syndicated loans from a consortium of banks may be tapped	To generate matching funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	60	Ensured long-term project funding for technology installation on PPP basis
Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;	To generate immediate and long-term funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	80	Ensured long-term project funding for technology installation on PPP basis
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Advanced Combustion Turbine Technology	To identify technical and institutional capacity gaps.	Power Division; private sector; Domestic & foreign private sector companies	2013-2017	70	Identified capacity gap of the respective power sector institutions
Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Domestic & foreign private sector companies	2013-2017	130	Power sector Institutions are staffed with skilled and expert human resource
Strengthening capacity of technical and managerial personnel of both	To help policy makers and other stakeholders to prioritize actions and make	Power Division; Private sector companies	2013-2017	80	Readily available comprehensive action plan for the policy

public and private enterprises	investment decision on the priority action.				makers and investors
Organizational/ behavioral change					
Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology	To facilitate cooperation and information sharing between institutions and experts	Power Division; Domestic & foreign private sector companies	2013-2017	80	Increased sharing of information among experts and institutions.
Policy and law					
Reviewing of Power Sector Master Plan to facilitate private investment on power generation	To facilitate private sector investment in power generation	Power Division; Ministry of Planning, Ministry of Finance	2013-2017	75	Developed private sector supportive laws and policies to leverage investment in power generation.
Solving of IPR issues through international cooperation and coordination.	To have free access to the advanced tools and technologies	Power Division;; Ministry of Science and Technology; WIPO	2013-2017	60	Removed IPR barriers in accessing modern tools technologies
Establishing clear institutional framework and policy for PPP	To facilitate private sector involvement in power generation sector	MoPMR, Power Division; Planning and Finance ministry;	2013-2023	80	Developed private sector supportive institutional framework and policy to leverage investment in power generation.

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.5 Technology action plan for Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 13: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology	Investment	Making detail cost estimation with the targeted implementation timeline of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology	√	
		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
		Syndicated loans from a consortium of banks may be tapped		√
		Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;		√
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology	√	
		Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	√	
		Developing of a comprehensive action plan for technical and institutional capacity building	√	

	Organizational/ behavioral change	Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	√	
	Laws/ Policy	Reviewing private sector power generation policy to encourage private sector investment in power generation	√	
		Solving of IPR issues through international cooperation and coordination.	√	
		Establishing clear institutional framework and policy for PPP		√

b) Technology Action Plan

Table 14: Technology action plan for Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology

Sector: Power generation					
Specific technology: Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2017	100	Readily available detail const estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Ministry of Planning	2013-2017	80	Communicated technology specific proposal to the development partners and private sector

mitigation funding sources					investors
Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;	To generate immediate and long-term funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	80	Ensured long-term project funding for technology installation on PPP basis
Syndicated loans from a consortium of banks may be tapped	To generate matching funds from national international sources.	Power Division; Domestic & foreign private sector companies	2013-2023	50	Ensured long-term project funding for technology installation on PPP basis
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology	To identify technical and institutional capacity gaps.	Power Division; private sector; Domestic & foreign private sector companies	2013-2017	75	Identified capacity gap of the respective power sector institutions
Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	130	Power sector Institutions are staffed with skilled and expert human resource
Developing of a comprehensive	To help policy makers and other	Power Division;	2013-2017	80	Readily available

action plan for technical and institutional capacity building	stakeholders to prioritize actions and make investment decision on the priority action.	Ministry of Planning, Ministry of Finance			comprehensive action plan for the policy makers and investors
Organizational/ behavioral change					
Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	To facilitate cooperation and information sharing between institutions and experts	Power Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	75	Increased sharing of information among experts and institutions.
Policy and law					
Reviewing private sector power generation policy to encourage private sector investment in power generation	To facilitate private sector investment in power generation	Power Division; Ministry of Planning, Ministry of Finance	2013-2017	80	Developed private sector supportive laws and policies to leverage investment in power generation.
Solving of IPR issues through international cooperation and coordination.	To have free access to the advanced tools and technologies	Power Division; Ministry of Science and Technology; WIPO	2013-2017	60	Removed IPR barriers in accessing modern tools technologies
Establishing clear institutional framework and policy for PPP	To facilitate private sector involvement in power generation sector	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2023	70	Developed private sector supportive institutional framework and policy to leverage investment in power generation.

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.6 Technology action plan for Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 15: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology	Investment	Making detail cost estimation with the targeted implementation timeline of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology	√	
		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
		Organizing Syndicated loans from a consortium of banks		√
		Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;		√
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology	√	
		Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	√	
		Developing of a comprehensive action plan for technical and institutional capacity building	√	

	Organizational/ behavioral change	Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	√	
	Laws/ Policy	Reviewing private sector power generation policy to encourage private sector investment in power generation	√	
		Solving of IPR issues through international cooperation and coordination.	√	
		Establishing clear institutional framework and policy for PPP		√

b) Technology Action Plan

Table 16: Technology action plan for Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology

Sector: Power generation					
Specific technology: Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Planning and Finance ministry; Private sector; WIPO	2013-2017	110	Readily available detail const estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development partners and other international mitigation funding	To ensure immediate and long-term funds from international sources.	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2017	70	Communicated technology specific proposal to the development partners and private sector investors

sources					
Organizing syndicated loans from a consortium of banks	To generate immediate and long-term funds from national international sources.	Power Division; IDCOL Domestic & foreign private sector companies	2013-2023	60	Ensured long-term project funding for technology installation on PPP basis
Introducing public-private partnership for resource mobilization as well as earning carbon credits on saved emission due to higher efficiency;	To generate matching funds from national international sources.	Power Division; Domestic & foreign private sector companies	2013-2023	90	Ensured long-term project funding for technology installation on PPP basis
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology	To identify technical and institutional capacity gaps.	Power Division; private sector; Domestic & foreign private sector companies	2013-2017	80	Identified capacity gap of the respective power sector institutions
Training for technical and managerial personnel for turn-key projects; for build-own-operate type of projects,	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Ministry of Science and Technology; private sector; Domestic & foreign private sector companies	2013-2017	140	Power sector Institutions are staffed with skilled and expert human resource
Developing of a comprehensive action plan for	To help policy makers and other stakeholders to		2013-2017	85	Readily available comprehensive

technical and institutional capacity building	prioritize actions and make investment decision on the priority action.				action plan for the policy makers and investors
Organizational/ behavioral change					
Establishing coordinated efforts among public and private institutions for knowledge sharing on the new technology.	To facilitate cooperation and information sharing between institutions and experts		2013-2017	60	Increased sharing of information among experts and institutions.
Policy and law					
Reviewing private sector power generation policy to encourage private sector investment in power generation	To facilitate private sector investment in power generation	Power Division; Ministry of Planning, Ministry of Finance	2013-2017	75	Developed private sector supportive laws and policies to leverage investment in power generation.
Solving of IPR issues through international cooperation and coordination.	To have free access to the advanced tools and technologies	Power Division; Ministry of Science and Technology; WIPO	2013-2023	70	Removed IPR barriers in accessing modern tools technologies
Establishing clear institutional framework and policy for PPP	To facilitate private sector involvement in power generation sector	MoPMR, Power Division; Ministry of Planning, Ministry of Finance	2013-2023	70	Developed private sector supportive institutional framework and policy to leverage investment in power generation.

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4.1.7 Technology action plan for Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)

a) Aggregation and grouping of identified measures

Following identification of measures in the stakeholder consultation workshop, the identified measures have been grouped under broader strategic measures presented in the table below;

Table 17: Grouping of measures under broader criteria

Technology	Strategic measures	Specific measure	Timeline	
			Short Term (1-5 years)	Long Term 1-10 years
Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)	Investment	Making detail cost estimation with the targeted implementation timeline of Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)	√	
		Making technology specific proposal and generating funds from the development partners and other international mitigation funding sources	√	
	Capacity development	Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)	√	
		Training for technical staff and experts for quality management	√	
		Strengthening capacity of technical and managerial personnel of both public and private enterprises	√	
		Developing of a comprehensive action plan for technical and institutional capacity building	√	
	Organizational/ behavioral change	Establishing coordinated efforts among public and private institutions for production of CFL and FL in national level	√	
		Introducing industrial regulatory measures for		

		maintaining technical standards of manufacturing locally		
		Making use of energy efficient components such as electronic ballasts mandatory, if necessary by providing tax breaks for their imports.	√	
		International and national coordination for research and development	√	
	Laws/ Policy	Incentive and other subsidy at the consumers level subsidy policy	√	
		Solving of IPR issues through international cooperation and coordination.		√
		Adoption of suitable tax policy	√	

b) Technology Action Plan

Table 18: Technology action plan for Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)

Sector: Power generation					
Specific technology: Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)					
Measures (Grouped under broader category)	Importance of the measure	Implementing agency	Timescale	Cost for the measures (1000 USD)	Monitoring, Reporting and verification for measure
	1	**2**	**3**	**4**	**5**
Investment					
Making detail cost estimation with the targeted implementation timeline of Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp (LF)	To help policy makers and investors to have a clear idea on investment requirement for the implementation of the technology.	MoPMR, Power Division; Ministry of Planning, Private sector	2013-2017	80	Readily available detail const estimation for the policy makers and investors
Making technology specific proposal and generating funds from the development	To ensure immediate and long-term funds from international	MoPMR, Power Division;	2013-2017	60	Communicated technology specific proposal to the development

partners and other international mitigation funding sources	sources.				partners and private sector investors
Capacity development					
Reviewing technical and institutional capacities of the existing public and private institutions for promotion and management of Compact Fluorescent lamp (CFL) and Linear Fluorescent lamp	To identify technical and institutional capacity gaps.	Power Division; Private sector;	2013-2017	50	Identified capacity gap of the respective power sector institutions
Training for technical staff and experts for quality management	To increase technical capacity of power sector experts, this in turn, will help designing and implementing build-own-operate type of projects	Power Division; Ministry of Science and Technology; Private sector;	2013-2017	90	Power sector Institutions are staffed with skilled and expert human resource
Developing of a comprehensive action plan for technical and institutional capacity building	To help policy makers and other stakeholders to prioritize actions and make investment decision on the priority action.	Power Division;	2013-2017	60	Readily available comprehensive action plan for the policy makers and investors
Organizational/ behavioral change					
Establishing coordinated efforts among public and private institutions for production of CFL and FL in national level	To facilitate cooperation and information sharing between institutions and experts	Power Division; Ministry of Science and Technology; Private sector;	2013-2017	40	Increased sharing of information among experts and institutions.

Introducing industrial regulatory measures for maintaining technical standards of manufacturing locally	To ensure high-quality and efficient products reaching to people	Power Division; Ministry of Science and Technology; Private sector;	2013-2017	70	Increased availability of quality products in the market
Making use of energy efficient components such as electronic ballasts mandatory, if necessary by providing tax breaks for their imports.	To ensure availability of quality and efficient product in the market	Power Division; Ministry of Science and Technology; Private sector;	2013-2017	70	Increased availability of quality products in the market
International and national coordination for research and development	To increase expertise and efficiency of local experts.		2013-2017	100	Local manufacturing industries and staffed with expert human resource
Policy and law					
Incentive and other subsidy at the consumers level	To facilitate market promotion of the product	Power Division;	2013-2017	80	Introduced a package of incentive and subsidy for better market promotion of the product
Solving of IPR issues through international cooperation and coordination.	To have free access to the advanced tools and technologies	Power Division; Planning and Finance ministry; Ministry of Science and Technology; WIPO	2013-2023	60	Removed IPR barriers in accessing modern tools technologies
Adopting suitable tax policy	To keep price of the solar PV systems lower	Power Division; Ministry of Planning, Ministry of Finance	2013-2017	75	Introduced market friendly policy

Note: In addition to the above cost the required capital operation and maintenance cost of the technology has been presented in the technology fact sheets (Annex I)

1.4. 2 Brief summary of project ideas for international support (Details in Annex 3)

The project idea is 'Installation of 1300 MW capacity Advanced Pulverized Coal (Double Unit) plant. Major objective of Advanced Pulverized Coal (Double Unit) project is to increase power supply that in turn will contribute to the country's growth and development.

1.5 Summary

Emission reduction from power generation and use can be achieved in several ways: by switching to low-carbon and renewable technologies, by increasing energy efficiency and by reducing demand for carbon-intensive products. Reducing non-fossil fuel emissions are also an important source of emission savings. Section I report of Technology Needs Assessment for Mitigation, however, focuses only on one of the ways, switching to low carbon intensive technologies in power generation and use this as a way to mitigate emissions.

The transfer and diffusion of the selected technologies will, therefore, depend largely on the development of enabling environment while overcoming the barriers. Below some of approaches for the developing enabling environment are presented:

a) The overarching issue in this effort though is the lack of and the need to improve *awareness* among policy-makers, planners and decision-makers about eco-efficiency concepts. This is the major cause of the weak response to date of the government to energy efficiency, conservation and renewable energy issues and it underscores the fact that a lot more needs to be done to mainstream energy efficiency and environmental issues in infrastructure projects which the TNA Report I shows has the largest scope for emission reductions.

b) In Bangladesh *the largest cut in emissions will come from the power sector* as the country embarks upon a very ambitious energy expansion program. Innovation, enterprise, policy support and institutional backing will be essential if a significant dent is to be made in creating efficiencies in this plan. However, it is apparent that there is a lack of *capacity* to develop, run and ensure proper maintenance of the technology.

c) The Bangladesh economy has been growing at above 6.5% even with a low energy supply base. This rate is expected to rise rapidly as energy availability improves, creating a twin energy challenge for the country: *improving environmental sustainability and enhancing energy security*. In the case of Bangladesh, an LDC facing liquidity constraints, an additional factor, *the availability of investible funds (especially for more expensive clean technologies),* must also be factored into the planning equation. By comparison capital costs of clean technologies are much higher for they embody research and development costs, deploying and disseminating costs and other costs such as those borne by consumers for switching to goods and services produced by the new technologies.

Given the above context, the transfer and diffusion of technologies will require considering of following factors in short-term and long-term measure;

a) Short Term Measures

- Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects,
- Establishing clear institutional framework and policy for PPP
- Reviewing of Private Sector Master Plan of power sector
- Developing community/ consumer level capacity on the maintenance of Solar PV Systems
- Adjusting tariffs, taxes for cheaper import of new more efficient components
- Training for technical staff and experts for quality management
- Adopting suitable tax policy
- Offering incentive and other subsidy at the consumers level i.e. subsidy policy

b) Long Term Measures

- Solving of IPR issues through international cooperation and coordination
- Establishing coordinated efforts among public and private financial institutions.
- Constant up-grading of the technology and ensuring diversified utilization of Solar home PV
- coordinating for research and development at international and national level
- Establishing coordinated efforts among public and private financial institutions for production of CFL and FL in national level
- Strengthening capacity of technical and managerial personnel of both public and private enterprises
- Training for technical and managerial personnel to be provided by vendors for turn-key projects; for build-own-operate type of projects,

Part III

Cross-cutting issues for the National TNA and TAPs

Part II of TNA report which is the action plan for the prioritized mitigation technologies, identified barriers in transfer and diffusion of technologies and identified measures to overcome the barriers. In addition to these, the TNA National Committee identified the following issues as cross-cutting which are to be considered for technology transfer and diffusion; these are

a) Recommendations for Policy Makers

The legal basis for implementing energy efficiency measures for energy conservation should be established by enacting a law on energy conservation, aimed at promoting energy conservation, creating the foundation for GoB regulation in the field of energy use and development of renewable energy (RE). To stimulate the introduction of renewable energy sources in the energy balance of the country, the law may provide tax incentives for investment in renewable energy and exemption from import duties on equipment for renewable energy.

For the investment of energy efficiency measures and the development of renewable energy sources can serve as GoB fund energy efficiency, financed by saving of energy efficiency measures. In order to implement productive activities and strategies for energy efficiency, a national body should be established in Bangladesh, which will be responsible for carrying out GoB policy on efficient use of energy resources and energy conservation.

In this context, it is important to address common barriers (e.g., fossil fuel subsidy, weak institutional capacity, high interest rates, etc.) and facilitate enabling policies and actions which can help address the barriers for multiple technologies and barriers.

This can justify some actions which are not critical to a technology, but importantly across a few technologies. Similarly, some actions to address the barriers for a technology may have some negative impact on the transfer and deployment of another technology. This also needs to be considered and suggestion made to limit the negative side effects of such actions.

b) Policy Measures to Promote Investment Priorities

To move the energy economy of Bangladesh to a sustainable path will require policy and institutional support to overcome market failures and barriers. Therefore, reforming the sector and providing policy support to deploy technology and innovation, develop human and institutional capacity, creation of a favorable regulatory framework and importantly, access to finance all measures that will promote a low carbon intensity sector have taken on an urgency. A recent study estimates that approximately $14.5 billion will be required by Bangladesh over the next two decades as financing to cover the incremental costs and risks of energy efficiency and renewable energy. In addition, substantial financing will be needed to build the capacity of local stakeholders and provide technical assistance.

Policy tools and financing mechanisms exist for such transformations. These are shown in the Table below; they are generic in nature and, therefore, need to be tailored to the national context. Implementing these will require strong political will and unprecedented international cooperation. Bangladesh has already begun to move in this direction. As a first step towards promoting energy efficiency, conservation and alternative sources of energy a government agency, the Sustainable Renewable Energy Development Agency (SREDA), is being finalized.

Policy Tools and Financing Sources

Abatement Measures	Energy Efficiency	Renewable Energy	New Technologies
Policy tools	Regulations & Financial incentives	Feed-in tariff or renewable portfolio standards	Support for R&D
	Financing Mechanisms	Tax on fossil fuel	Financing incremental cost
	Institutional Reforms	Promoting household PVs	Transfer technologies
Financing sources	TA Grants	TA Grants	TA Grants
	Concessional Financing	Concessional Financing	Concessional Financing
	Commercial public & private investment	Commercial public & private investment	Commercial public & private investment

c) **Consideration for the new technologies**: In the short term, new technologies such as Integrated Gasification Combined Cycle, or IGCC; will provide the largest source of emission abatement. Emission savings can be extremely large depending on the type of technology used. These technologies should be financed as a priority basis.

d) **Consideration for energy efficient technologies**: In the short-term, the second largest and cheapest source of emission reductions in Bangladesh is in improving the energy efficiencies in power, industry, buildings, and transport. Many of these interventions are financially viable but they have not been realized because of other factors such as market failures. In Bangladesh market failure is primarily caused by the low cost of energy which acts as a disincentive to reform. If the right policy and regulatory frameworks are in place cost of energy efficiency measures can be met from domestic investments although costs associated with incremental risks, with building capacity of financiers and energy service providers will need external concessional or TA type financings.

e) **Consideration of the renewable energy technologies**: Although the use of renewable energy presents immense opportunities in Bangladesh especially since prices of RETs have been declining dramatically, they are still not viable when compared to conventional energy in a financial sense although they are economically. This means that ways must be found to internalize externalities either through direct subsidies or through price increases of conventional energy. Under the right policy and regulatory regime, these technologies can become commercially viable. PV solar for household electricity shows great promise, by end 2011 more than a million systems will have been sold in Bangladesh; and other renewable based power from fluidized bed rice-husk technology also hold out good potential. As in other cases, baseline costs can come from domestic investors while international concessional financing and grants will be needed to cover incremental (costs above fossil fuels) and soft costs.

Historically, innovation and technology breakthroughs have reduced the costs of overcoming formidable technical barriers, given effective and timely policy action—a key challenge facing the world today. The largest barrier is the high incremental costs between these technologies and conventional options, particularly in developing countries. Effective, innovative, fair, and affordable ways are needed to accelerate the transfer of low-carbon technologies and the financing of incremental costs of these technologies to the developing world.

In fact, many policies exist which if implemented will lead to GHG emission reduction. But, most of these policies have not been implemented because of lack of funds, lack of political will, shortage of trained manpower, management deficiencies, and rules/regulations of public procurement policy which does not allow the purchase of the best technology. Until and unless these factors are tackled, it would be very difficult to achieve growth in the power and energy sector in line with GHG mitigation.

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Annexes

Annex I. Technology Factsheets for Power Generation and Use

A. Name of Technology: Advanced Gas Combustion Turbine

A.1 Introduction

Combustion turbine (CT)-based plants comprise the fastest growing technology in power generation. Almost all of these CT and combined cycle (CC) plants are gas fired, leading to a major expansion of gas based electricity generation. It is likely that combustion turbines and combined cycles will grow steadily in all generation regimes - peaking, mid-range and base load. Combustion turbine plants will be a competitive choice for new fossil generation, and advanced CT cycles, with intercooling, reheat, and possibly chemical recuperation and humidification; they will spearhead the drive to higher efficiencies and lower capital costs.

Under the Department of Energy Advanced Turbine System (ATS) program (DOE 2001), development work was carried out with two manufacturers to enhance the efficiency and environmental performance of utility-scale gas turbines. The goals were to achieve 60% efficiency or more in a combined-cycle mode; NOx emission levels less than 9 ppm; and a 10% reduction in the cost of electricity. To achieve the efficiency objective required significantly higher turbine inlet temperatures. These higher temperatures required advancements in materials, cooling systems, and low-NOx combustion techniques.

A.2 Technology characteristics

Advanced gas combustion turbines for power generation are mostly heavy-frame machines in a simple cycle configuration around 170-190 MW for the high firing temperatures (approx. 1250^{o}C) of the “F-class” machines. Efficiencies are 36%-38% in simple cycles. In combined cycles, the units are 260-380 MW in size and 53%-56% efficient. The next generation of CTs, with efficiencies from 57 to 60% is now emerging.

Several variants of the CT-based Brayton cycle increase plant efficiency and capacity:

1. *Regenerative cycle* uses storage type heat exchangers to store energy from the exhaust gases.
2. *Intercooling* between compressor stages reduce compressor work requirement, and therefore increases net turbine output power.
3. *Steam injection* directly into the combustion chamber increases the mass flow rate into the combustion chamber and therefore increases turbine output power.
4. *Inlet air cooling* increases the mass flow rate into the combustion chamber and therefore increases turbine output power, however some power is consumed to cool the inlet air.

A.3 Country specific / applicability

Almost all of these CT and combined cycle (CC) plants are gas fired, leading to a major expansion of gas based electricity generation. This technology is suitable for Bangladesh as Bangladesh has the primary fuel (Gas) to fed into the technology for power generation

A.4 Status of technology in country

Limited usage in the country

A.5 Barriers

- Costly, but not as high as others in similar category – yet the price tag for a typical 210 MW plant is US$ 140 mn or more.
- Present power sector master plan needs revision for emphasis on Advanced CT;
- Private sector foreign direct investment not allowed at the moment
- The ACT has many variants; the F-class has been considered here as this the most proven technology. However, class 'H' is exhibiting good performance and stability, and therefore should be considered in future. In some regions of Bangladesh, there is limited gas availability and supply gas pressure requires boosting costing considerable initial and operating costs.

A.6 Benefits to economic / social and environmental development

- Productivity may increase as with cheaper and stable supply of electricity. New technology may be introduced in the factories or the operating time of factories may lengthen. On the other hand, better supply may spur the establishment of new factories and facilities and various service centers.
- Job creation, both direct and indirect, will be facilitated because of productivity increase or the establishment of new enterprises. - Poverty will be reduced as more and more jobs are created.
- These machineries are to be imported from abroad and more sophisticated technology may require higher initial cost. However, because of higher efficiency and stability, these turbines will be with shorter break-even time.

A.7 Costs

Capital Costs:

- The cost of an ACT is 665/kW and a CT 974/kW. Given that the capacity of a ACT is 210 MW and that of a CT is 85 MW, the price tag of a CT with equal capacity as ACT is 2.47 times the cost/kW of each CT. That is for a CT it is 2.47*US$ 974//kW which comes to US$ 204 mn compared to an ACT of same capacity at just about US$140 mn. There is thus a huge cost advantage of ACT over CT.

Operational and Maintenance costs:

- Fixed O&M costs are for CT: US$ 6.98 and for ACT: 6.70 per year per kW. The differences are small on a kW basis, but when the comparison on an equivalent capacity basis is made, the costs for fixed O&M for CT becomes US$ 1.46 mn and for ACT US$ 1.40 mn. The differences are rather small and may be ignored for comparative purposes.
- The case for variable O&M is however quite different. For CT it is 14.70/MWh and for ACT it is 9.87/MWh. If we assume that the two are run exactly the same number of hours in a year, CT variable O&M costs become US$24 mn and for ACT US$16 mn at the most. Again a somewhat clear cost advantage for ACT over CT for the same level of output.

Cost of GHG Emission:

- As the capital costs are far lower for ACT and the fixed O&M costs are similar while variable O&M costs are somewhat less for ACT for a year's run time, this means that the 10% lower emission is achieved at negative costs.

B. Name of Technology: Natural Gas Combined Cycle

B.1 Introduction

The term *combined cycle* refers to any power plant system in which a high temperature thermodynamic cycle (*topping cycle*) rejects heat to a low temperature cycle (*bottoming cycle*), ordinarily employing a different working fluid. *Combined-cycle plant* has now become the accepted shorthand for the term *combined cycle, gas-turbine-steam plant*.

The simplest form of combined cycle power plant, as shown in Figure blow, is a single-pressure system. The major components present in the cycle are a single-pressure heat recovery steam generator (HRSG), a steam turbine, a water-cooled condenser, and a deaerater. The air is compressed inside the compressor and is supplied to the combustion chamber. The fuel (natural gas) from the main supply line is compressed in gas compressors and injected into the combustion chamber. The air and fuel mix together and then the combustion products leave the combustion chamber.

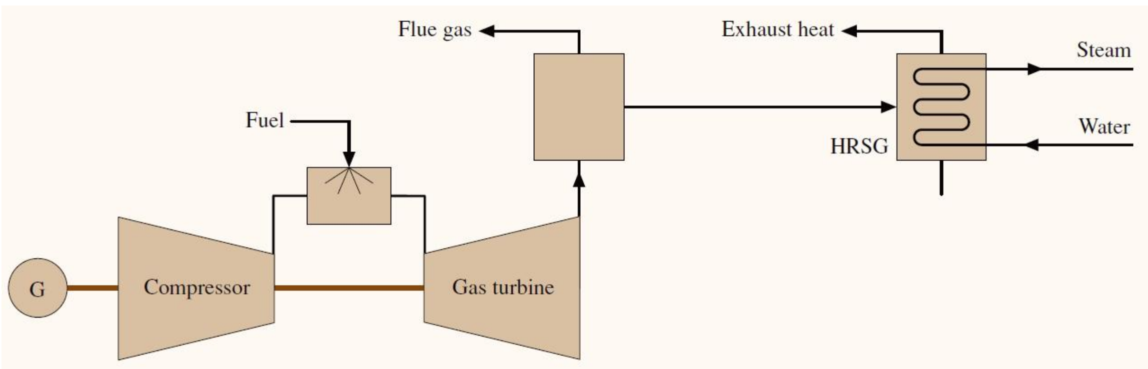


Figure 2. Layout of a gas turbine cogeneration system

The combustion products from the combustion chamber enter the gas turbine and there expand to a low pressure and hence mechanical power is produced by the turbine; and electricity is produced by the generator connected to the turbine. Exhaust gas leaving the gas turbine is then supplied to the heat recovery steam generator (HRSG) to produce superheated steam in the bottoming steam cycle.

B.2 Technology characteristics

A gas turbine unit exhausting into a heat recovery steam generator (HRSG) that supplies steam to a steam turbine cycle is the most efficient combined cycle power generation system generating electricity today. There are six main advantages of a combined gas turbine and steam turbine cycle:

1. Higher overall plant efficiency
2. Higher availability
3. Shorter design and construction period
4. Reduced emission levels
5. Environmentally friendly power generation
6. Rapid-load change and start up capability

B.3 Country specific / applicability

Power generation

B.4 Status of technology in country

Widely used in Bangladesh

B.5 Barriers

- Costly as capital costs for a typical plant size of 540 MW may come US$ 500-600 mn.
- Present power sector master plan may need revision for emphasis on NGCC;
- Private sector foreign direct investment not allowed at the moment
- Combined cycle plants are well-known; Capacity to technologically manage large, modern generation unit is limited although have some experience of running combined cycle

B.6 Benefits to economic / social and environmental development

- Productivity may increase as with cheaper and stable supply of electricity. New technology may be introduced in the factories or the operating time of factories may lengthen. On the other hand, better supply may spur the establishment of new factories and facilities and various service centers.
- Job creation, both direct and indirect, will be facilitated because of productivity increase or the establishment of new enterprises.
- Poverty will be reduced as more and more jobs are created.
- BoP these machineries are to be imported from abroad and more sophisticated technology may require higher initial cost. However, because of higher efficiency and stability, these turbines will be with shorter break-even time.

B.7 Costs

Capital Costs:

- The costs of a NGCC unit is 978/kW and of a CT 974/kW. Given that the capacity of a NGCC is 540 MW and that of a CT is 85 MW, for equivalent capacity, the price tag of a CT establishment with equal capacity as NGCC is 6.35 times the cost/kW of a single CT unit. That is for a CT it is 6.35*US$ 974//kW which comes to US$ 525 mn compared to an NGCC of same capacity at just about US$528 mn.

Operational and Maintenance costs:

- Fixed O&M costs are for CT US$ 6.98 and for NGCC 14.39 per year per kw. The differences are around double on a kw basis, but for comparison on an equivalent capacity basis, the costs for CT gets to US$ 3.77 mn and for NGCC US$ 7.77 mn.
- The case for variable O&M is however quite different. For CT it is 14.70/MWh and for NGCC it is 3.43/MWh. If we assume that the two are run exactly the same number of hours in a year (320 days for 24 hours), CT variable O&M costs become US$ 60.9 mn and for NGCC US$14 mn at the most, a very clear cost advantage for NGCC over CT for the same level of output.

Cost of GHG Emission:

- If CT is replaced with NGCC, for equivalent output of CT as for NGCC, the reduction in CO2 emission as pointed out earlier is 0.84 mn mt per year. The yearly operational costs are estimated to be US$ 64.67 mn for CT equivalent to an NGCC while for the latter it is US$ 21.77 mn. Noting that if we assume similar life cycle for the two types of plants, the cost of depreciation of capital is more or less the same. The lower emission is thus achieved at a negative (operational and total) cost.

Economic feasibility

-The NGCC is a tested technology and its technical feasibility is probably not questioned. It is also to be noted that the present level of technology is much more efficient than before and uses much less primary fuel due to technical improvements. Here we provide an illustrative case of economic feasibility that has been conducted in 2011 for establishing in Ashuganj a combined cycle plant. The base case scenario and the sensitivity analyses are as follows:

The base case for a 450 MW combined cycle plant at 2010 prices was US$ 410.50 mn. The economic cost of the project was estimated to be US$ 453 mn. The base EIRR was 49%. Sensitivity analyses show that if capital costs increase by 10%, benefits are down by 10%, fuel costs rise by 20%, O&M costs rise by 20%, the project is delayed by a year, all of them happening together, even then the EIRR remains extremely good at 37.5%.

C. Name of Technology: Advanced Generation Natural Gas Combined Cycle

C.1 Introduction

The Conventional NGCC technology utilizes two natural gas-fueled F-class CTs and associated electric generators, two supplemental-fired heat recovery steam generators (“HRSG”), and one condensing ST and associated electric generator operating in combined-cycle mode.

C.2 Technology characteristics

C.3 Country specific / applicability

Power generation

C.4 Status of technology in country

Currently not in use and not available

C.5 Barriers

- Costly as capital costs for a typical plant size of 400 MW may come US$ 400 mn or more.
- Present power sector master plan need revision for emphasis on ANGCC;
- Private sector foreign direct investment for such technological improvement may be given further support under the Private Power Generation Policy.
- ANGCC are not well-known;
- Capacity to technologically manage large, modern generation unit is limited particularly as there is no ANGCC in country

C.6 Benefits to economic / social and environmental development

While the actual lowering of CO_2 emission depends on the run time of the plant and production, note that the heat rate is somewhat lower compared to the conventional gas turbine and thus, the emission of CO_2 is expected to be lower per kwh. The lowering of CO_2 emission depends on the nominal heat rate as the rate of emission is 117 lb per MMbtu for both NGCC and conventional turbine.

Gross CO_2 emission for a 400MW AG-NGCC is 1.05 mn mt. For CT with equivalent capacity, gross CO_2 emission is 1.77 mn mt. Thus, the emission from an AG-NGCC is lower by 0.72 mn mt or 40% less from CT of equivalent capacity in a year

C.7 Costs

Capital Costs:

- The investment cost of an ***AG-NGCC plant*** is US$ 1,003/kW and for a CT it is US$ 974/kW. Given that the capacity of a ***AG-NGCC*** is 400 MW and that of a CT is 85 MW, for equivalent capacity, the price tag of a CT with equal capacity as ***AG-NGCC*** is 4.7 times the cost/kW of CT. That is for a CT it is 4.7*US$ 974//kW which comes to US$ 389 mn compared to an ***AG-NGCC*** of same capacity at just about US$401 mn. There is thus a small investment cost advantage of CT over ***AG-NGCC.***

Operational and Maintenance costs:

- Fixed O&M costs are for CT is US$ 6.98 and for AG-NGCC it is US$ 14.62 per year per kw i.e., almost double that for CT. When the comparison is made on an equivalent capacity basis, the costs for CT gets to US$ 2.79 mn and for AG-NGCC it becomes US$ 5.85 mn which is more than double the cost for equivalent capacity with CT.
- The case for variable O&M is however quite different. For CT it is 14.70/MWh and for ***AG-NGCC*** it is 3.11/MWh. If we assume that the two are run exactly the same number of hours in a year (320 days for 24 hours /day), CT variable O&M costs become US$ 45.10 mn and for ***AG-NGCC*** US$ 9.55 mn at the most. There is thus a very clear cost advantage in terms of variable O&M for ***AG-NGCC*** over CT for the same level of output

Cost of GHG Emission:

- If CT is replaced with AG-NGCC, for equivalent output of CT as for AG-NGCC, the reduction in CO2 emission as pointed out earlier is 0.72 mn mt per year. The yearly operational costs are estimated to be US$ 47.89 mn for CT equivalent to an AG-NGCC while for the latter it is US$ 15.40 mn. Noting that if we assume similar life cycle for the two types of plants, the cost of depreciation of capital for AG.NGCC may be is more or less the same as for equivalent CT or slightly more. The lower emission is thus achieved at a negative (operational and total) or almost equivalent cost.

D. Name of Technology: Advanced Pulverized Coal (Single Unit)

D.1 Introduction

D.2 Technology characteristics

In steam power plants using pulverized coals, finely powdered coal is mixed with air and transported in the furnace where it is burnt in a flame similar to the flame of a liquid or gaseous fuel. Hence, it is possible to design and build large steam boilers so that it could operate with whatever fuel is economically available by just changing the burner. Boiler furnace is designed to perform two functions simultaneously, namely:

- The release of the chemical energy of fuel by combustion: the first task of combustion technology is to burn the fuel efficiently and steadily, to consume controlled excess air (as little as possible).
- To generate a flame with a controlled shape that will generate the lowest amount of pollutants and ensure the transfer of heat from the furnace to the working fluid inside the water walls.

Fuel enters the furnace in the form of particles less than about 100 microns in size – a dust is so fine that it floats. The dust is swept in a controlled flow of air to the burner jets. With the tiny particles, the fixed carbons burns out completely in a very short time, so the volatile matter and the fixed carbon burn together in roughly the same part of the furnace, increasing the efficiency of heat transfer.

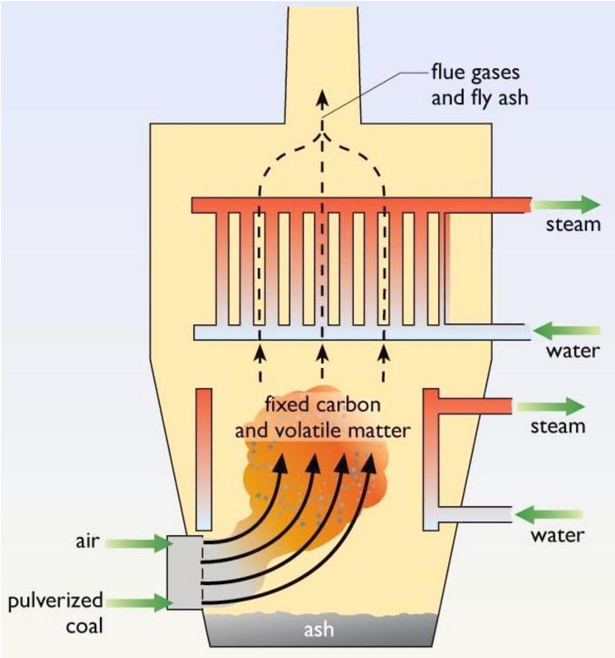


Figure 3. Pulverized fuel burner

Combustion takes place in large furnace which is surrounded by vertical boiler tubes joined together to form continuous *waterwall* that absorbs the intense thermal radiation heat flux from the burning fuel. Thus a large fraction of heat of combustion is quickly removed as the hot gases pass upward through the furnace into the second-stage superheater, then across through the reheater and through the first-stage superheater and economizer, and finally through the air preheater to the stack.

Such technologies are referred to as "clean coal technologies" and described by a family of pre-combustion, combustion–conversion, and post-combustion technologies. They are designed to provide the coal user with added technical capabilities and flexibility and the world with an opportunity to exploit its most abundant fossil source. They can be categorized as:

1. *Pre-combustion*: Sulfur and other impurities are removed from the fuel before it is burned.
2. *Combustion*: Techniques to prevent pollutant emissions are applied in the boiler while the coal burns.
3. *Post-combustion*: The flue gas released from the boiler is treated to reduce its content of pollutants.
4. *Conversion*: Coal, rather than being burned, is changed into a gas or liquid that can be cleaned and used as a fuel.

Thus, together with the potential impact of carbon dioxide emissions contributing to global warming, the control of particulates, sulfur dioxides and nitrogen oxides from those plants is one of the most pressing needs of today and the future. To combat these concerns, a worldwide move toward environmental retrofitting of older fossil-fired power plants is underway, focused largely on sulfur dioxide scrubbers and combustion or post-combustion optimization for nitrogen oxides. Carbon dioxide control and sequestration options are now under study worldwide.

D.3 Country specific / applicability

Power Generation

D.4 Status of technology in country

Currently not in use

D.5 Barriers

- Costs constitute a major barrier along with complexity in case of APCC-single and double units with price tags of more than US$2 bn for a typical 650 MW single unit or nearly US$ 4bn for a double unit (1300 MW) plant; coals transport, and other infrastructure will raise costs further
- Present power sector master plan may need revision for emphasis on NGCC;
- Private sector foreign direct investment not allowed at the moment
- A proven but somewhat complex technology, particularly its size may lead to major managerial difficulties both technically and otherwise, regularity of supply of primary fuel may be a critical bottleneck if supply chains are not contractually spread over several years in future and proper coal handling facilities not created beforehand which will raise costs further; IPR may also be a problem

- Capacity to technologically manage such very large, modern generation unit is practically non-existent and so is the experience of super critical coal plants

D.6 Benefits to economic / social and environmental development

The benchmark as argued should perhaps be the pulverised sub-critical plant. Unfortunately it is difficult to get comparable figures for sub-critical plants. Hence, we use the CT as the reference point. In fact, perhaps that is what it should be as the most prevalent mitigation friendly power generation technology in Bangladesh is the conventional combustion turbine. Hence, the comparison may be with CT.

- A serious disadvantage of pulverized coal boilers is that the ash is a fine dust, and without measures to prevent it, this fly ash will be carried into the atmosphere with the flue gases. Depending on the ash content of the coal, the power station may also produce 25 tonnes or more of ash per hour. In European countries, pulverized fuel ash is commonly used for construction purposes, such as being mixed with cement and turned into lightweight concrete blocks. This effectively locks up much of the heavy metal contents.

D.7 Costs

Capital Costs:

- The investment cost of a single unit APC is US$ 3,167/kW. Given that the capacity of a single unit APC is 650 MW the price tag of a single unit APC is US$ 3,167*650000 or 2.06 bn. For CT of equivalent capacity it is only US$ 633.34 mn. Going for a coal-based supercritical technology as one unit establishment, is thus going to be extremely costly compared to gas-based generation.

Operational and Maintenance costs:

- Fixed O&M costs are for single unit APC US$ 35.97 per year per kW. Thus for a single unit estimated APC fixed cost is US$ 23.38 mn. For a CT of comparable capacity, the fixed cost becomes US$ 4.54 mn.
- Variable O&M for single unit APC it is 4.25/MWh and the total comes to US$ 21.21 mn per year. For CT of equivalent power generation, the total variable O& M costs come to US$73.41 mn. Thus CT variable O& M costs are much higher compared to APC single unit.

Cost of GHG Emission:

- The emission actually increases, not reduced, from equivalent CT-based generation. Hence the cost of reduction is redundant

E Name of Technology: Advanced Pulverized Coal (Double Unit)

E.1 Introduction

Advanced Pulverized Coal Facility is provided for a nominally 650 MW coal-fired supercritical steam-electric generating unit which employs a supercritical Rankine power cycle in which coal is burned to produce steam in a boiler, which is used to run a ST to produce electric power. The steam is then condensed to water and pumped back to the boiler to be converted to steam once again to complete the cycle.

Steam pressures for these units are typically 240 bar, most of them single reheat designs. Steam temperatures are usually limited to about 594°C, in order to utilize all-ferrite materials for thick wall components. A few utilize higher steam temperatures. The increased pressures and temperatures provide significant efficiency improvements over subcritical units, with attendant reductions in environmental emissions: SOx, NOx, CO_2, and particulates.

E.2 Technology characteristics

Pulverized coal power generation starts by crushing coal into a fine powder that is fed into a boiler where it is burned to create heat. The heat produces steam that is used to spin one or more turbines to generate electricity. Subcritical plants make up the bulk of the U.S. pulverized coal system, with efficiencies for new plants usually around 37 percent. Pulverised sub-critical plants can be taken to be the benchmark for evaluating super critical, ultra super critical and IGCC plants

E.3 Country specific / applicability

Power generation

E.4 Status of technology in country

Not available in Bangladesh, and only limited numbers in the world. The greatest concentration of installed units is in the countries of former USSR, USA and Japan.

E.5 Barriers

- Costs constitute a major barrier along with complexity in case of APCC-single and double units with price tags of more than US$2 bn for a typical 650 MW single unit or nearly US$ 4bn for a double unit (1300 MW) plant; coals transport, and other infrastructure will raise costs further
- Present power sector master plan may need revision for emphasis on NGCC;
- Private sector foreign direct investment not allowed at the moment
- A proven but somewhat complex technology, particularly its size may lead to major managerial difficulties both technically and otherwise, regularity of supply of primary fuel may be a critical bottleneck if supply chains are not contractually spread over several years in future and proper coal handling facilities not created beforehand which will raise costs further; IPR may also be a problem
- Capacity to technologically manage such very large, modern generation unit is practically non-existent and so is the experience of super critical coal plants

E.6 Benefits to economic / social and environmental development

Each of the double unit APCs will produce nominally 1300 MW. This is more than double the capacity of even the NGCC typical plant size of 540 MW. Thus the additional output will allow more electricity to the citizens to consume allowing a better quality of life.

With increased supply of electricity, and consequent access to it, the lighting for studies will improve leading to better education prospects as well as security. The process of women’s empowerment will be better served as with increased access to electricity the may enjoy facilities to which their access was limited previously.

E.7 Costs

Capital Costs:

The investment cost of a double unit APC is US$ 2,844/kW. Given that the capacity of a double unit APC is 1300 MW the price tag of a double unit APC is US$ 2.844*130000 or 3.70 bn. For CT of equivalent capacity it is only US$ 1.26 bn. Going for a coal-based supercritical technology as one unit establishment, is thus going to almost 3 times costly investment compared to benchmark gas-based generation.

Operational and Maintenance costs:

Fixed O&M costs are for double unit APC US$ 29.67 per year per kW. Thus for a double unit APC fixed cost is US$ 35.06 mn. For a CT of comparable capacity, the fixed cost becomes US$ 9.07 mn.

Variable O&M for double unit APC it is 4.25/MW h and the total comes to US$ 42.4 mn per year. For CT of equivalent power generation, the total variable O& M costs come to US$146.72 mn. Thus CT variable O& M costs are almost three times as much compared to APC double unit.

Cost of GHG Emission:

The emission actually increases and is not reduced, from equivalent CT-based generation. Hence, the cost of reduction is redundant.

F. Name of Technology: Single Unit Integrated Gasification Combined Cycle

F.1 Introduction

Integrated Gasification Combined Cycle (IGCC) technology makes possible the utilization of low cost coal and opportunity fuels, such as petroleum coke, residual oil and biomass, for clean efficient and cost effective electricity generation. Recent increases in natural gas prices and concerns about its availability, as well as significant advances in air separation, gasification and syngas cleanup technologies, have made coal and opportunity fuels based Integrated Gasification Combined Cycle (IGCC) plants a competitive option for efficient and environmentally safe power generation compared to direct fired pulverized coal plants and natural gas fired combined cycle (CC) plants.

Coal gasification generally refers to the reaction of coal with oxygen and steam, to yield a gaseous product for use directly as a fuel in a power plant or as a feed to synthesis of other gaseous or liquid chemicals. Gasification is, in essence, an incomplete combustion. There are similarities between coal combustion and gasification, but the pollutant formation processes are different in gasification. The latter is classified as a clean-coal technology, because under reducing conditions, sulfur from coal is converted mostly to H_2S rather than SO_2, and nitrogen is converted mostly to NH_3, and almost no NO_x is formed.

Syngas from the gasifier is cleaned of its hydrogen sulfide, ammonia, and particulate matter and is fed into a gas turbine where it is mixed inside the combustion chamber with hot pressurized air from the compressor. The final hot combustion products drive the gas turbine. The hot combustion gases from the gas turbine are used to produce steam in the steam generator. The steam drives the steam turbine, which produces 30–40% of the total electricity output. An air separation unit is also employed in modern IGCC power plants. Nitrogen and oxygen are completely separated in the air separator, from which pure oxygen is fed into the gasifier to reduce carbon dioxide emissions and the inert gas nitrogen is very well utilized in the gas turbine.

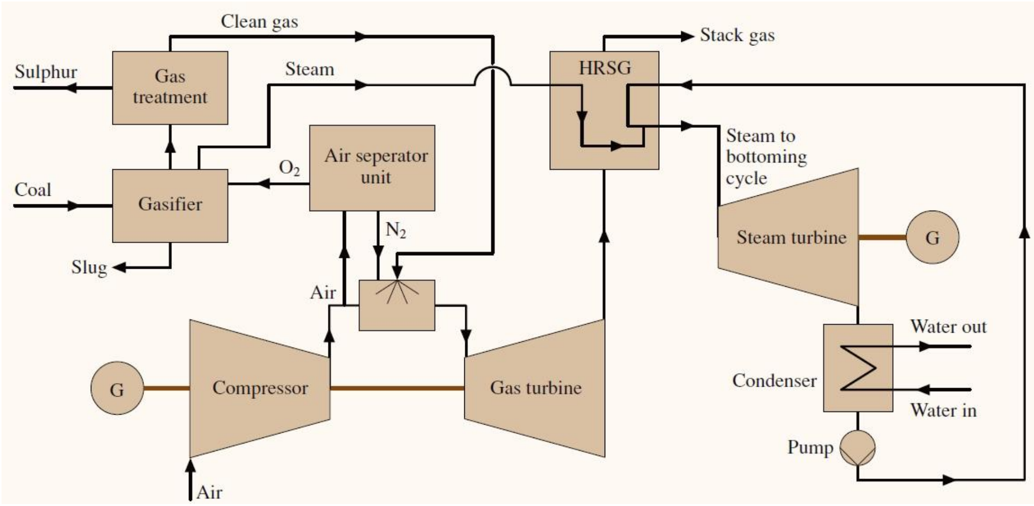


Figure 4 . Layout of an integrated gasification combined-cycle power plant

The technology makes use of the thermodynamic advantages provided by combining two different cycles: a gas turbine cycle and steam turbine cycle. Cleaning the gas before combustion provides benefits over the treatment of flue gases: a much smaller quantity of gas has to be treated and in addition the composition of the coal gas is such that it allows easier purification. The purification process could possibly be extended and could also permit the elimination of exhaust carbon dioxide. Hence, this technology has been proposed as the basis for a low-CO2-emission coal power plant with CO2 capture. Ample gasification processes have to be selected and the integration and optimization of all the processes are crucial for the overall efficiency. Coal gas clean up is another critical issue.

F.2 Technology characteristics IGCC systems combine several desired attributes and are becoming an increasingly attractive option among the emerging technologies. First, IGCC plants provide high-efficiency energy conversion (up to 44 percent), with the prospect of even higher efficiencies if higher temperature turbines or viable hot gas cleanup systems are employed. Second, very low emission levels for sulfur and nitrogen species have been demonstrated at many facilities around the world. Third, IGCC plants produce flue gas streams with concentrated CO2, as well as high levels of carbon monoxide that can be easily converted to CO2. Recovery of CO2 in IGCC systems is potentially less expensive than in the conventional combustion systems. Moreover, CO2 recovery can be done in conjunction with hydrogen sulphide removal by using several commercial technologies.

In IGCC systems, environmental control is required not just to meet environmental regulations but also for proper plant operation. In particular, contaminants such as sulfur, particulates, and alkali must be removed prior to fuel gas combustion to protect the gas turbine components from erosion, corrosion, and deposition. The approach to emissions control in an IGCC plant is fundamentally different from that in a pulverized-coal-fired power plant. Emission control strategies focus on the fuel gas, which is pressurized and has a substantially lower volumetric flow rate than the flue gas, which flows near atmospheric pressure of coal combustion power plants. Furthermore, sulfur in the fuel gas is in reduced form (mostly H2S), which can be removed by a variety of commercially available processes. Another attractive feature of IGCC technology is that it can be progressively implemented in new or existing plants. This technology is modular in nature and offers the possibilities of phased construction.

F.3 Country specific / applicability

In some regions of Bangladesh, natural gas supply for power generation is not available. Hence, IGCC power generation may provide economical and stable power supply.

F.4 Status of technology in country

Not in use

F.5 Barriers

- IGCCs are very costly – US$ 2-4 bn depending on whether single or double units; O&M costs are also not insubstantial
- Present power sector master plan need revision for emphasis on IGCC;
- Private sector foreign direct investment may be allowed further incentives than at present
- IGCC is a new technology, not yet in many countries and protected by IPR
- Capacity to technologically manage such very large, modern generation unit is practically non-existent and so is the experience of super critical coal plants

F.6 Benefits to economic / social and environmental development

The main incentives for IGCC technology development and application are the low fuel costs, significant reduction in emissions and high efficiency in future plants. The current IGCC plant capital costs with CO2 capture are higher than for conventional coal based plants. However, the availability and abundance of coal, petroleum coke and residual oil, help to make IGCC's cost of electricity and total plant life cycle costs more competitive. The development of a syngas/hydrogen capable combustion system is the key prerequisite for the successful gas turbine

Environmental Benefits

1. Coal that contains high sulfur content can be very well utilized in IGCC plant. During the coal gasification process the sulfur in the coal appears as hydrogen sulphide; capturing hydrogen sulphide is not a tedious task. In some IGCC plants the sulfur can be extracted in a form that can be sold commercially.
2. Likewise, nitrogen typically exits as ammonia and can be scrubbed from the coal gas by processes that produce fertilizers or other ammonia-based chemicals.
3. If oxygen is used in a coal gasifier instead of air, carbon dioxide is emitted as a concentrated gas stream. In this form, it can be captured more easily and at lower costs for ultimate disposition in various sequestration approaches.

Efficiency Benefits

Efficiency gain is another benefit of IGCC plants. The fuel efficiency of IGCC power plant can be boosted to 50% or more. Future insights that integrate a fuel cell could achieve even higher efficiencies, maybe in the 60% range, which is nearly twice the value of today's typical coal-fired power plants. Higher efficiencies translate into more economical electric power and potential savings for ratepayers. A more efficient plant also uses less fuel to generate power, meaning that less carbon dioxide is produced. IGCC plants with the flexibility to produce chemicals such as ammonia and hydrogen along with electricity make this a promising technology for future generations.

Each of the single unit IGCCs will produce almost the same of the nominal output of single unit APCs. This will allow more electricity to the citizens to consume allowing a better quality of life.

With increased supply of electricity, and consequent access to it, the lighting for studies will improve leading to better education prospects as well as security. The process of women's empowerment will be better served as with increased access to electricity the may enjoy facilities to which their access was limited previously.

F.7 Costs

Capital Costs:

The costs of a single unit IGCC is 3,565/kW and a single unit APC 3,167/kW. Given that the capacity of a single unit IGCC is 600 MW and that of a single unit APC is 650 MW, for equivalent capacity, the price tag of a single unit APC with equal capacity as single unit IGCC is somewhat similar. For a single unit APC it is US$ 1900 mn compared to an IGCC of same capacity at just about US$ 2139 mn. There is thus a about 10% cost advantage for investment in a of single unit APC over single unit IGCC

Operational and Maintenance costs:

Fixed O&M costs are for single unit APC US$ 35.97and for single unit IGCC 59.23 per year per kW. The differences are large on a kW basis, but when the comparison on an equivalent capacity basis, the costs for single unit APC gets to US$ 23.38 mn and for single unit IGCC US$ 38.50 mn. The absolute difference is also somewhat large.

The case for variable O&M is however quite different. For single unit APC it is 4.25/MWh and for single unit IGCC it is 6.87/MWh. If we assume that the two are run exactly the same number of hours in a year, single unit APC variable O&M costs become US$21.2mn and for single unit IGCC US$31.65 mn or so. Again a clear cost advantage for single unit APC over single unit IGCC for the same level of output.

Cost of GHG Emission:

Compared to the gas-based CT which may be used as the benchmark, because of the similarity of the generation part of the technology, the estimated CO2 emission is higher for single unit IGCC. And thus, the issue of cost of reduction does not arise.

G. Name of Technology: Double Unit Integrated Gasification Combined Cycle

G.1 Introduction

The Double Unit Single Unit IGCC power plant is basically a dual unit of the single unit IGCC plant. As discussed earlier, IGCC is a new power generation system, consisting of a gassifier which gasifies coal to CO and H2 and separates ash from coal, a gas clean-up facility which separates dust and sulfur from the resulting gas, and a gas turbine combined cycle power plant using coal gas from the gas clean-up facility.

G.2 Technology characteristics

IGCC has a potential of higher than 50% net thermal efficiency with increased gas turbine combustion temperature, as this has already been realized with natural gas fired combined cycle power plants. It will also result in a 20% reduction of CO_2 while generating the same amount of electricity using coal. Although many research and development projects aimed at CO_2 reduction and fixation have been carried out worldwide, it appears difficult to achieve an economical and industrial scale. Thus, it is clear that increased net thermal efficiency is the most practical way for reduction of CO_2, making IGCC an attractive and important technology for the next century. Another feature of IGCC is its superior environmental performance which is attained by means of the conversion process from ‘‘dirty’’ coal to ‘‘clean’’ purified gas and disposal of non-leaching glassy slag in place of fly ash.

G.3 Country specific / applicability

In some regions of Bangladesh, natural gas supply for power generation is not available. Hence, IGCC power generation may provide economical and stable power supply.

G.4 Status of technology in country

Not in use in Bangladesh.

G.5 Barriers

- IGCCs are very costly – US$ 2-4 bn depending on whether single or double units; O&M costs are also not insubstantial
- Present power sector master plan needs revision for emphasis on IGCC;
- Private sector foreign direct investment may be allowed further incentives than at present
- IGCC is a new technology, not yet in many countries and protected by IPR
- Capacity to technologically manage such very large, modern generation unit is practically non-existent and so is the experience of super critical coal plants

G.6 Benefits to economic / social and environmental development

Each of the double unit IGCCs may produce 1200 MW of electricity. This will allow more electricity to the citizens to consume allowing a better quality of life.

With increased supply of electricity, and consequent access to it, the lighting for studies will improve leading to better education prospects as well as security. The process of women's empowerment will be better served as with increased access to electricity the may enjoy facilities to which their access was limited previously**.**

G.7 Costs

Capital Costs:

The costs of a dual unit IGCC is 3,221/kW and a single unit APC 3,167/kW. Given that the capacity of a dual unit IGCC is 1,200 MW and that of a single unit APC is 650 MW, for equivalent capacity, the price tag of a single unit APC with equal capacity as single unit IGCC are quite similar. That is for a single unit APC it is 1.85*US$ 3,167//kW which comes to US$ 3808.3mn compared to an dual unit IGCC of same capacity at just about US$3865.2mn.

Operational and Maintenance costs:

Fixed O&M costs are for single unit APC US$ 35.97and for double unit IGCC US$ 48.90 per year per kW. Compared to the double unit APC, the differences are even larger as the fixed cost of double unit APC is US$ 29.67/kW/year While the differences are large on a kW basis, when the comparison is made on an equivalent capacity basis, the fixed costs for a single unit APC gets to US$ 43.2 mn and for dual unit IGCC US$ 58.7 mn which means a relative narrowing of difference despite the large disparity in size between the two.

The case for variable O&M is however quite different. For single unit APC it is 4.25/MWh and for dual unit IGCC it is 6.87/MWh. If we assume that the two are run exactly the same number of hours in a year (320 days ona 24 hour basis), single unit APC variable O&M costs becomes US$ 39.25 mn and for dual unit IGCC US$ 63.31 mn. This shows again a very clear cost advantage for single unit APC over dual unit IGCC for the same level of output

Cost of GHG Emission:

Compared to the gas-based CT which may be used as the benchmark for GHG reduction comparison because of the similarity of the generation part of the technology, the estimated CO2 emission is higher for double unit IGCC. And thus, the issue of cost of reduction does not arise.

H. Name of Technology: Solar PV

H.1 Introduction

The sun acts as an atomic furnace as it converts mass into a huge amount of energy, according to Einstein's mass - energy relation $E = mc2$. Ultimately solar energy is free and results in no hazard to the environment. In sunny countries, solar power can be used where there is no easy way to supply electricity to a remote place. It is also convenient for low-power devices such as solar-powered garden lights and battery chargers. There are various ways to produce electricity from the energy obtained from the sun.

A solar panel is made up of the natural element silicon, which becomes charged electrically when subjected to sunlight. Sunlight is composed of packets of energy called photons. These photons contain various amounts of energy corresponding to the different wavelengths of light. The solar cell is made up of a material with well-defined possible energy levels for electrons. When a photon is absorbed in the active material, the energy of the photon is transferred to an electron, which becomes excited from a low to a higher energy level.

The asymmetric structure of the solar cell ensures that this electron escapes from its normal position, carrying away the extra energy. This electron leaves the cell through a metal contact and becomes part of the current in an electrical circuit.

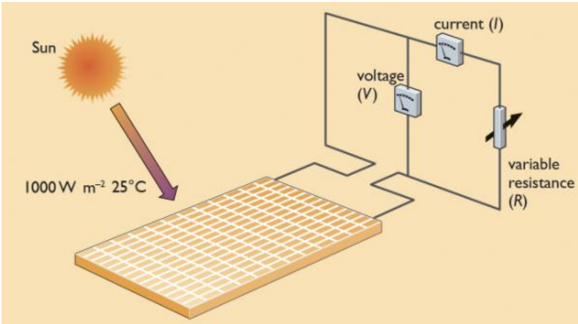


Figure 5. Solar PV system

H.2 Technology characteristics

Power Generation (Renewable)

H.3 Country specific / applicability

The PV Facility uses numerous arrays of ground-mounted, fixed-tilt PV modules which directly convert incident solar radiation into DC electricity, which can then be inverted to AC. the basic structure of a photovoltaic cell consisting of p-conducting base material and an n-conducting layer on the topside. The entire cell rear side is covered with a metallic contact while the irradiated side is equipped with a finger-type contact system to minimize shading losses. Also full cover, transparent conductive layers are used. To reduce reflection losses the cell surface may additionally be provided with an anti-reflecting coating. A silicon solar cell with such construction usually has a blue color. By the incorporation of inverse pyramids into the surface reflection losses are further reduced. The inclination of the pyramid surfaces is such that photons are reflected onto another pyramid surface, and thus considerably enhance the possibility of photon penetration into the crystal.

H.4 Status of technology in country

Till recently, solar power generation has been limited to installation of rather small solar PV systems at homes and small establishments in rural and off-grid areas. However, the Government is aware that despite limitations, there may be scopes for power generation based on solar energy

H.5 Barriers

- Home-based solar PVs are costly for poor households particularly as many demand higher capacity systems.
- Only off-grid areas are expected to be under solar home system, but apparently there is unmet demand also in grid-based areas; present policy does not allow grid-based areas to be under solar
- Little major technological problem exists; but updating of technology needed for catering to higher demand in existing and future connected homes; batteries pose problems as this is the costliest part and also problem of battery disposal for much faster expansion of the system
- Little capacity related problem so far

H.6 Benefits to economic / social and environmental development

Each of the small solar unit will produce more or less 7 MW. Being small, these may be suitable in off-grid areas for small communities as well as for commercial enterprises. This may allow a quality supply and ensure access of the people in poorer and remote region.

With new supply of electricity, and consequent access to it, it may be used for all kinds of economic and domestic uses including lighting. Lighting for studies will improve leading to better education prospects as well as security. The process of women's empowerment will be better served as with new access to electricity they may enjoy facilities to which their access was limited previously**.**

H.7 Costs

Capital Costs:

The costs of a small solar PV is US$ 6050 /kW compared to the costliest gas-based technology of US$2060/kW and costliest coal-based technology of US$ 5348 both including carbon capture and storage and state of the art technology. The total costs are however not large as the capacity is small.

Operational and Maintenance costs:

Fixed O&M costs are not comparatively high, at US$ 26.04/kW-year. **Cost of GHG Emission:**

The total cost of a solar PV is the cost of GHG reduction from plants that it replaces which is not unique by country. But as the capital costs are rather high, for equivalent power production the costs of zero emission under solar PV are rather high

I. Name of Technology: Linear fluorescent lamp

I.1 Introduction

Now-a-days, fluorescent lamps have almost completely supplanted incandescent lamps in all fields except specialty lighting and residential use. The typical linear fluorescent lamp comprises a cylindrical glass tube sealed at both ends and containing a mixture of an inert gas, generally argon, and *low-pressure* mercury vapor. Built into each end of the tube is a cathode that supplies the electrons to start and maintain an electric arc, or gaseous discharge. Short-wave UV radiation, which is produced by the mercury arc, is absorbed by phosphors coating the inside of the tube, causing a reaction that emits visible radiation (light).

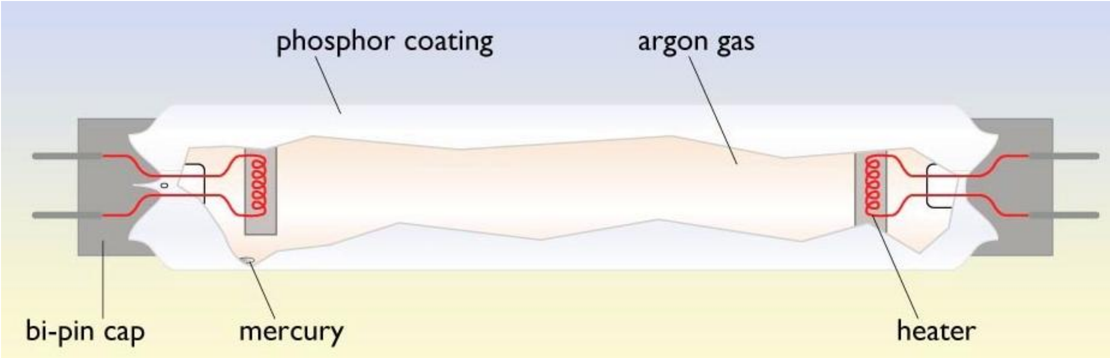


Figure 6. The basic linear fluorescent tube lamp

The particular mixture of phosphors used governs the quantity and spectral quality of the light output. Light from fluorescent sources radiates from a larger lamp surface area than is the case with incandescent sources. The light is diffuse, which is suitable for illuminating or washing large areas such as ceiling planes.

I.2 Technology characteristics

Five characteristics define the operation of fluorescent lamps:

1. *Efficacy* - light output per unit of power input
2. *Lumen maintenance* - the decreasing output of light as a lamp ages
3. *Lamp life* - average (statistically defined) lamp life expectancy
4. *Temperature and humidity* - how a lamp responds to extreme environmental operating conditions.
5. *Dimming* - output reduction of a fluorescent lamp

Comparative characteristics of fluorescent lamps of different types are shown in Table below:

Lamp Types	T12	T8	T5	T5H0
Initial rated light output	3350 lumens	2950 lumens	2900 lumens	5000 lumens
Nominal lamp watts	40 W	32 W	28 W	54 W
System efficacy	69 lm/W	84 lm/W	86 lm/W	81 lm/W
Rated life	20,000 hr	20,000 hr	16,000 hr	16,000 hr
Optimum operating temperature	25ºC	25ºC	35ºC	35ºC

All gaseous discharge lamps, e.g. fluorescent lamp, require a ballast to trigger the lamp with a high ignition voltage and to control the amount of electric current for proper operation. The function of ballast is threefold:

1. To supply controlled voltage to heat the lamp filaments in preheat and rapid-start circuits
2. To supply sufficient voltage to start the lamp by striking an arc through the tube
3. To limit the lamp current once the lamp is started

There are three basic types of ballasts:

1. *Magnetic.* Magnetic ballasts (core-and-coil) contain a magnetic core of several laminated steel plates wrapped with copper windings, and they operate at line frequency. These ballasts have become essentially obsolete, although they are found in existing buildings.
2. *Hybrid.* Also called cathode-disconnect ballasts, hybrid ballasts use a magnetic core-and-coil transformer and an electronic switch for the electrode-heating unit. Like magnetic ballasts, they operate at line frequency. The ballast disconnects the electrode-heating unit after starting the lamp.
3. *Electronic.* Solid-state electronic ballasts operate lamps at 20 to 60 kHz and have less power loss than magnetic ballasts. Lamp efficacy increases by approximately 10% to 15% compared to operation at line frequency. Electronic ballasts are lighter, more energy-efficient, generate less heat, and are virtually silent. They are also available as dimming ballasts, which allow light output to be controlled between 1% and 100%.

I.3 Country specific / applicability

Standard linear fluorescent lamps are widely used in residential, commercial and industrial applications.

I.4 Status of technology in country

Fluorescent lamps are rather well-known. The problem is in price compared to incandescent lamps. Particularly, a LFL needs ballast as well as a starter and also a holder.

The nominal lumen capacity, relative efficiency and life lengths are 55-85 per watt, 65% and up to 24000 hours depending on particular designs. The lowest life is 7500 hours

I.5 Benefits to economic / social and environmental development

- With better lighting quality, study habits may change for the better leading to better education prospects as well as security
- Productivity may increase as with better quality of light, workers' incentive to work may improve
- Poverty may be reduced because people may have more time to engage in income-earning activities due to better lighting
- Little direct impact on air pollution may result from the use of LFLs. But the disposal of unusable tubes may create a problem due to the presence of mercury in them which may be leaked to the air or may be leached into the ground water

I.6 Costs

Capital Costs:

The costs of an incandescent bulb may vary from US$ 1-3 while for an LFL it ranges from US$ 2.5-6

Operational and Maintenance costs:

An LFL needs special ballast, a starter and holders while an incandescent bulb needs none. But an LFL lasts far longer 10-20 thousand hours compared to 750 hours-1200 or so for an incandescent lamp. Thus, the latter needs to be replaced far more often than an LFL. The O&M costs for the incandescent is high (roughly 20 times the purchase cost of an average 60 W bulb. O & M for LFL is much less because it is infrequent but costlier each time.

Cost of GHG Emission:

While many factors may impinge upon the actual emission reduction and the costs, it appears that the cost may not be high on a life-cycle analysis basis.

J Name of Technology: Compact Fluorescent Lamp

J.1 Introduction

Compact fluorescent lamps (CFLs) offer a comparable (in brightness and color rendition), energy-efficient alternative to incandescent lamps. Unlike standard fluorescent lamps, they can directly replace standard incandescent bulbs. CFLs are simply folded fluorescent tubes with both ends terminating in a common base. Some compact fluorescent lamps have the tubes and ballast permanently connected with a screw-in medium base. Others have separate tubes and ballasts, allowing the tubes to be replaced without changing the ballast. As a result, an exhausted lamp is simply replaced while retaining the existing ballast, resulting in considerable economy. A CFL produces a diffuse light, unlike single-point incandescent lamps. This is an important factor to consider when replacing incandescent with CFLs in high ceiling applications.

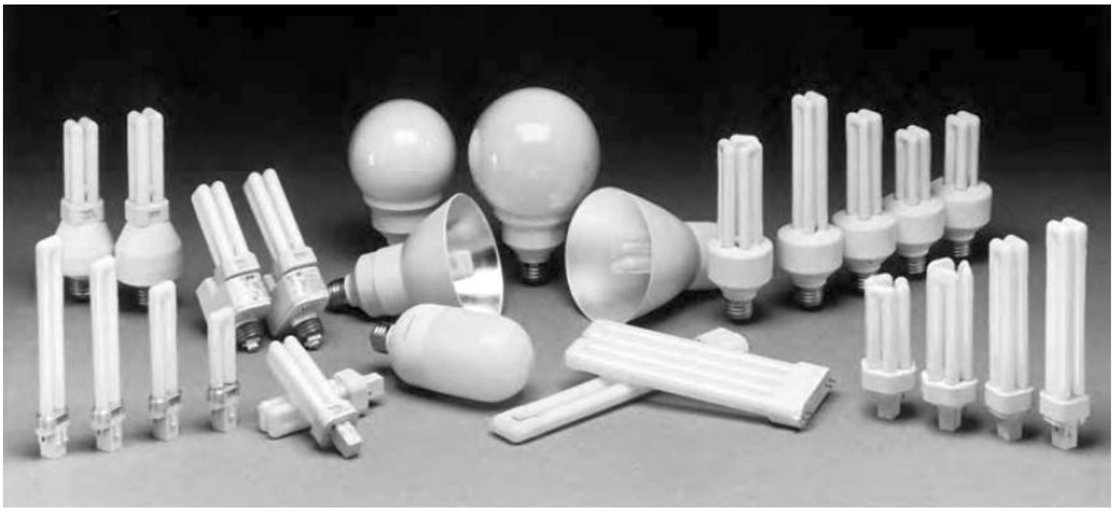


Figure 7. Family portrait of compact fluorescent lamp designs.

J.2 Technology characteristics

CFLs are manufactured in a variety of styles or shapes: two, four, or six tubes; circular or spiral tubes. They are efficient at lower wattages and can produce light output equivalent to that of higher-wattage incandescent (e.g., a typical 60-W incandescent lamp with a 900-lumen output could be replaced by a 15- to 19-W CFL). The total surface area of the tube(s) determines how much light is produced. The efficacy of lamp-ballast combinations ranges from 55 to 75 lm/W, assuming electronic ballast. Lamps with magnetic ballasts are available but are not favored because of excessive heat, weight, flicker, and reduced efficiency. Lamp colors are similar to straight lamps (i.e., 3000 K, 3500 K, 4200 K, and 5000 K). All CFLs have a

CRI of 80 or higher. Their life is 10,000 to 12,000 hours based on 3 hours per start. The wattage of commonly available incandescent lamps to that of a CFL that provides similar light output is compared below:

Incandescent Watts	Compact Fluorescent Watts
9	50
60	15
75	20
100	25
120	28
150	39

J.3 Country specific / applicability

CFLs are less well-known than LFLs the latter being in the market far longer and also because it is much cheaper. Compact fluorescent lamps are far costlier compared to incandescent lamps and this is a major barrier to its widespread use. However, their use in residential, commercial and industrial applications is increasing day-by-day.

J.4 Status of technology in country

Compact fluorescent is a new technology with a history of about 40 years and new developments for bettering its performance is continuing. It uses the same basic features as for the LFLs but introducing design and other changes. It has already generated legislations in many countries to phase out incandescent bulbs with CFLs or other similarly energy-saving lighting technology. A CFL of 23 W produce the same light as an incandescent bulb of 100 W i.e., a CFL uses 75% less power than an incandescent lamp to produce the same lumen.

J.5 Benefits to economic / social and environmental development

- With better lighting quality, study habits may change for the better leading to better education prospects as well as security
- Productivity may increase as with better quality of light, workers' incentive to work may improve. Also security in the work place may become better
- Poverty may be reduced because people may have more time to engage in income-earning activities due to better lighting
- There will be a 75% fall in use of electricity for lighting for the same number of hours implying positive outcome on resource use

J.6 Costs

Capital Costs:

The costs of an incandescent bulb may vary from US$ 1-3 while for a CFL it is at least US$ 10.

Operational and Maintenance costs:

A CFL needs ballast. These days it comes integrated with the lamp and thus fixed costs are little or none. It does not generally need to be replaced for 10,000 hours although the actual life may get reduced if the on-off cycle is rather short (15 minutes to half hour). A CFL lasts far longer 10 thousand hours compared to an average of 1000 hours. The latter needs to be replaced about 10 times, whereas the CFL has to be replaced only once. But because CFL investment cost is far higher, the over-all O&M costs may not be much different.

Cost of GHG Emission:

While many factors may impinge upon the actual emission reduction and the costs, it appears that the cost may not be high on a life cycle analysis basis. In fact it may be near zero if the investment costs and O&M costs for equivalent hours (10,000) for CFL and incandescent lamps are considered.

Annex II. Market maps for Technologies

The market map of consumer goods has been done to conceptualize, visually represent and communicate knowledge about the entire commercial and institutional environment in which specific market chains of specific technology operates. In this exercise, stakeholders and experts discussed and exchanged information to build up a comprehensive picture of the entire existing system, while they consider following aspect

Relating to market demand:
- Consumption trends (prices, volumes and quality expectations)
- Taxes, subsidies and tariff regimes

Relating to transformation activities, i.e., the costs of doing business:
- Infrastructure constraints and investment policies
- Transport policies and licensing
- Technological development
- Trade regime (import/export)

Relating to transaction activities:
- Systems of finance
- Registration of land and property
- Legal requirements for contracts
- Commercial law and practices
- Business licenses and regulation
- Standards quality control and enforcement

The relevant other factors that also are considered include:

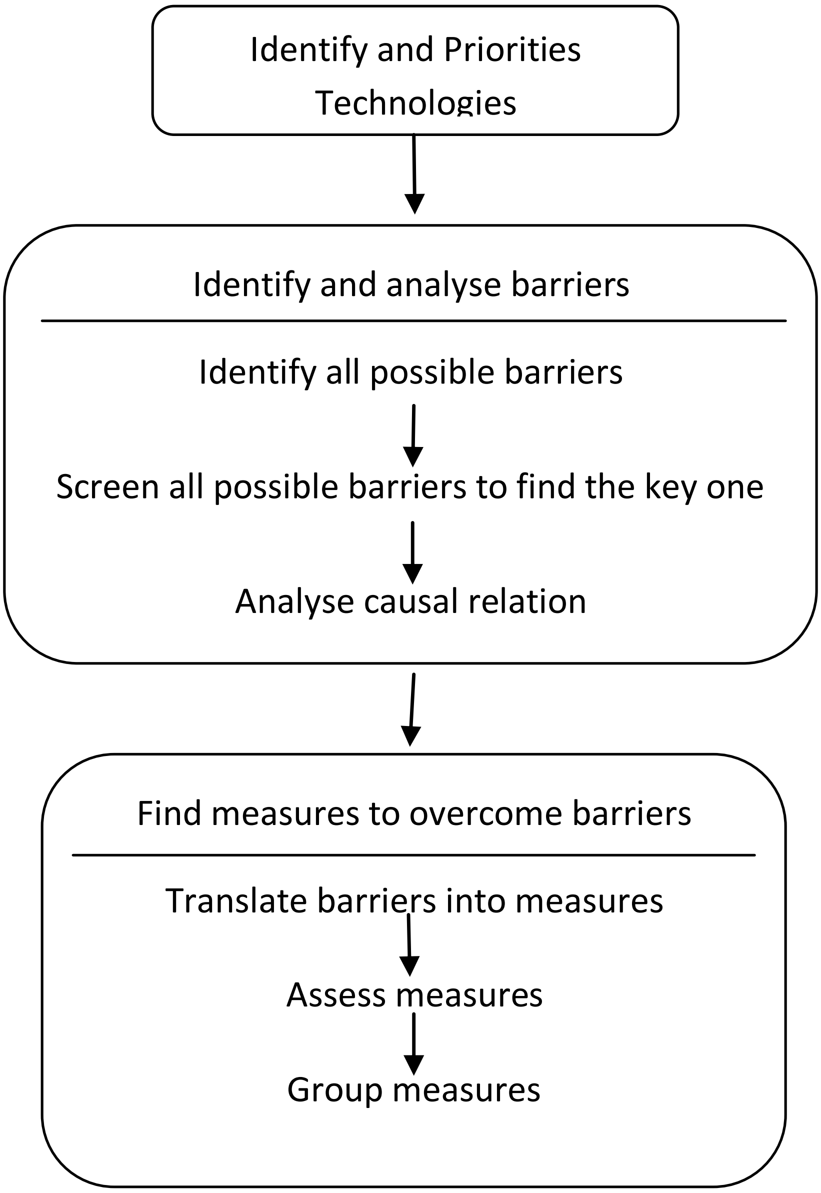
- Environment that allows the introduction of new technologies (such as legal, institutional, organizational)
- The relevant object in the system (such as manufacturers, wholesalers, retail dealers, consumers, households producer)
- Supporting services (such as finance, quality management, performance, standard, etc.)

The market mapping is only applicable for technologies which are classified as capital goods. Among mitigation technologies, there are 3 technologies of consumer goods category; they are Solar TV, Compact Fluorescent Lamps and Linear fluorescent lamp. The other mitigation technologies are of capital goods category. For Solar PV technology, the market chain includes production, importer, retailer and consumer.

Both for Compact Fluorescent Lamp (CFL) and Linear Fluorescent Lamp technology, the market chain includes production; dealer/whole seller; retailers and consumers. In marker chain the factors that influences transfer and diffusion of this new technology includes prices, effect, benefit, quality standards, capital cost etc. Price is a common concern to the dealer, retailers and even to the consumers. If the price is too high compared with the benefits it brings, they will think a lot before buying. Therefore, high price can be considered as a barrier during the transfer and diffusion of this technology. There are also several measures to overcome the barrier such as reducing tax, subsidies, waver of import tarrifs etc. that could reduce products price. Consumers care and ensuring maintenance services are also major important factors diffusion and transfer of technologies. Besides affordable price factor, the consumers also consider product standard and quality. To maintain and upscale product quality research, development, international cooperation is required.

Specific market maps for Solar PV, Compact Fluorescent Lamp (CFL) and Linear Fluorescent Lamp technology are presented below.

On the other hand, maps of analysing framework condition for capital goods of mitigation technologies have been developed based on two processes: Identifying and analysing barriers process and measures to overcome barriers process is given in the below figure:



Annex II

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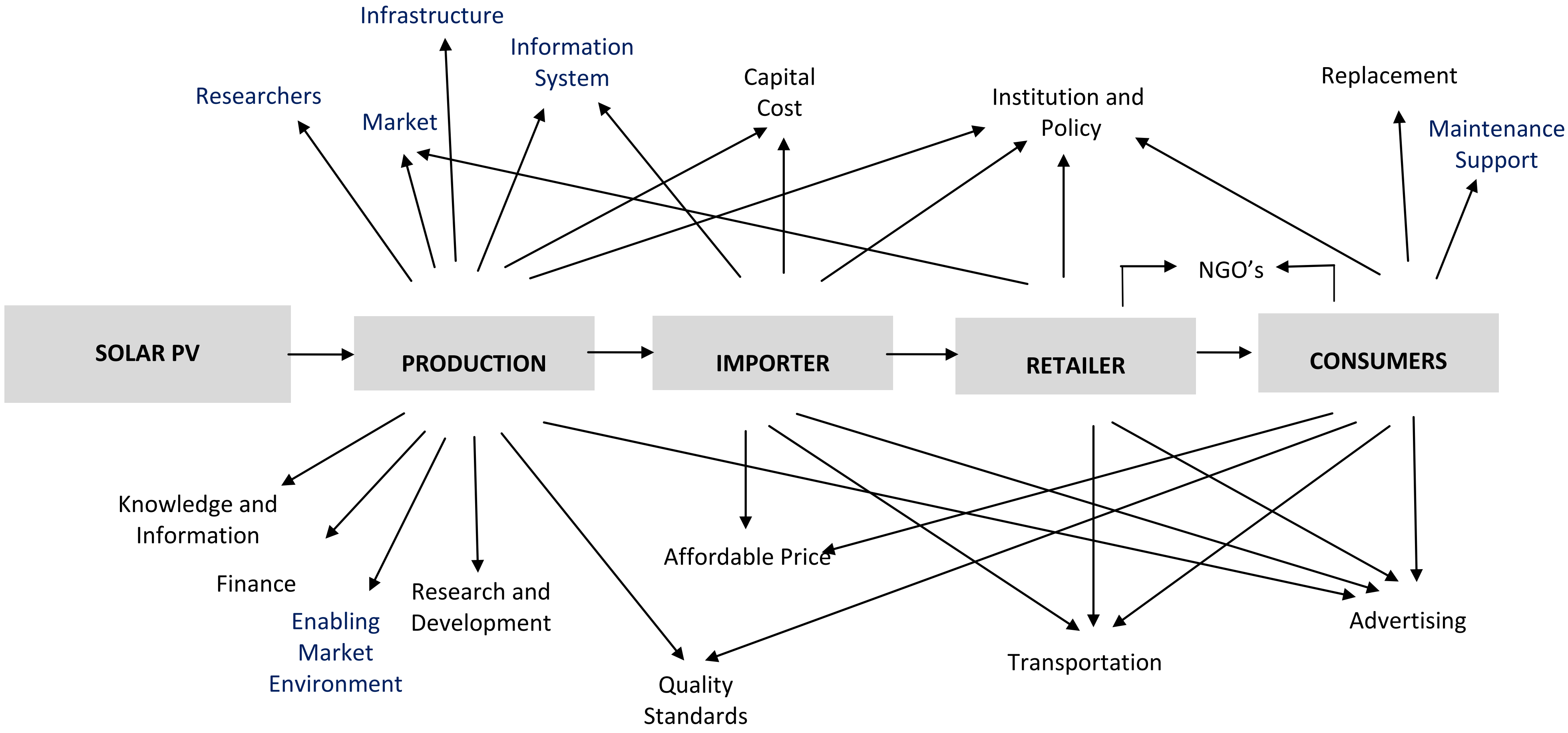

Figure 8: Market map for Solar PV

Annex II

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figure

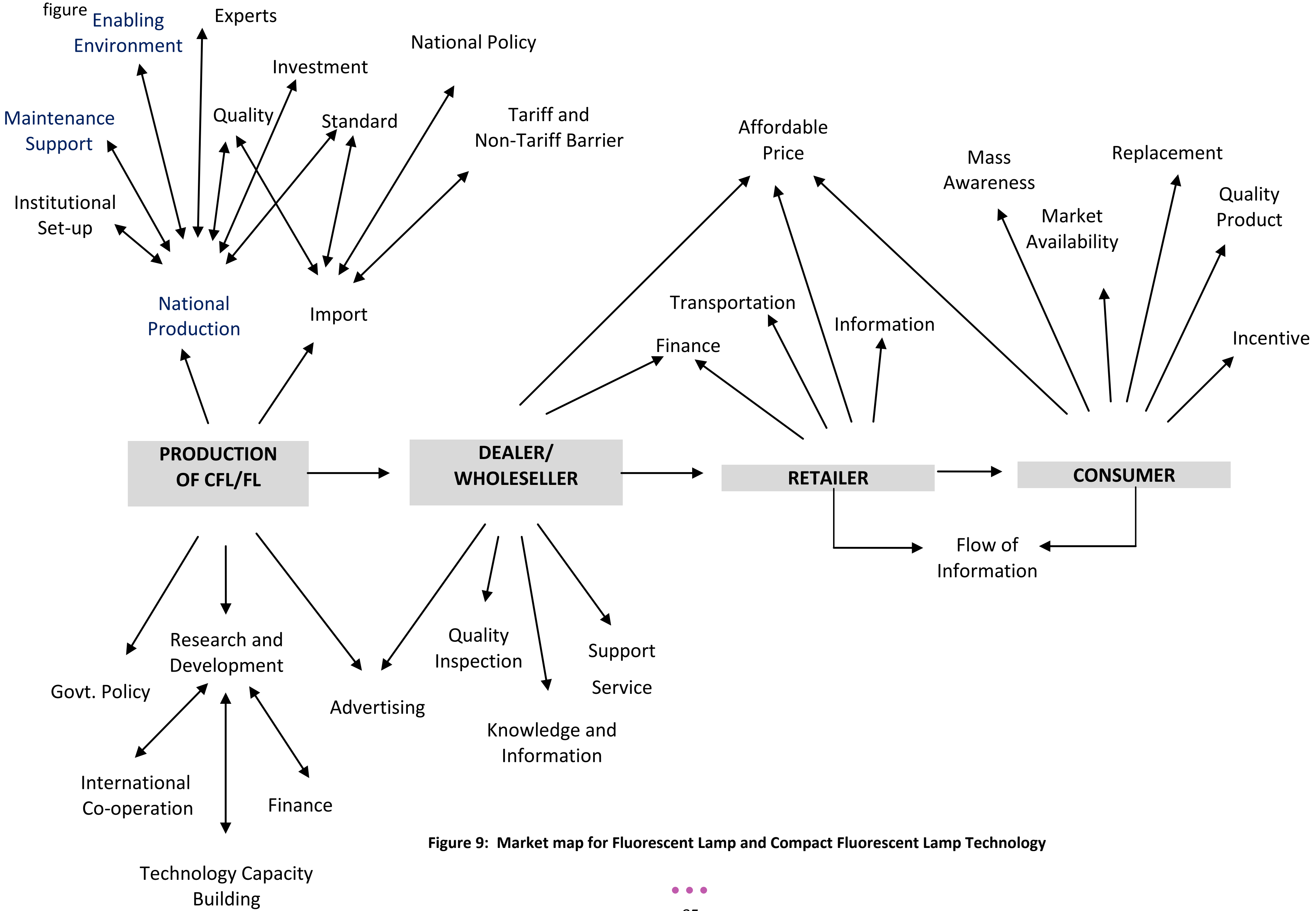

Figure 9: Market map for Fluorescent Lamp and Compact Fluorescent Lamp Technology

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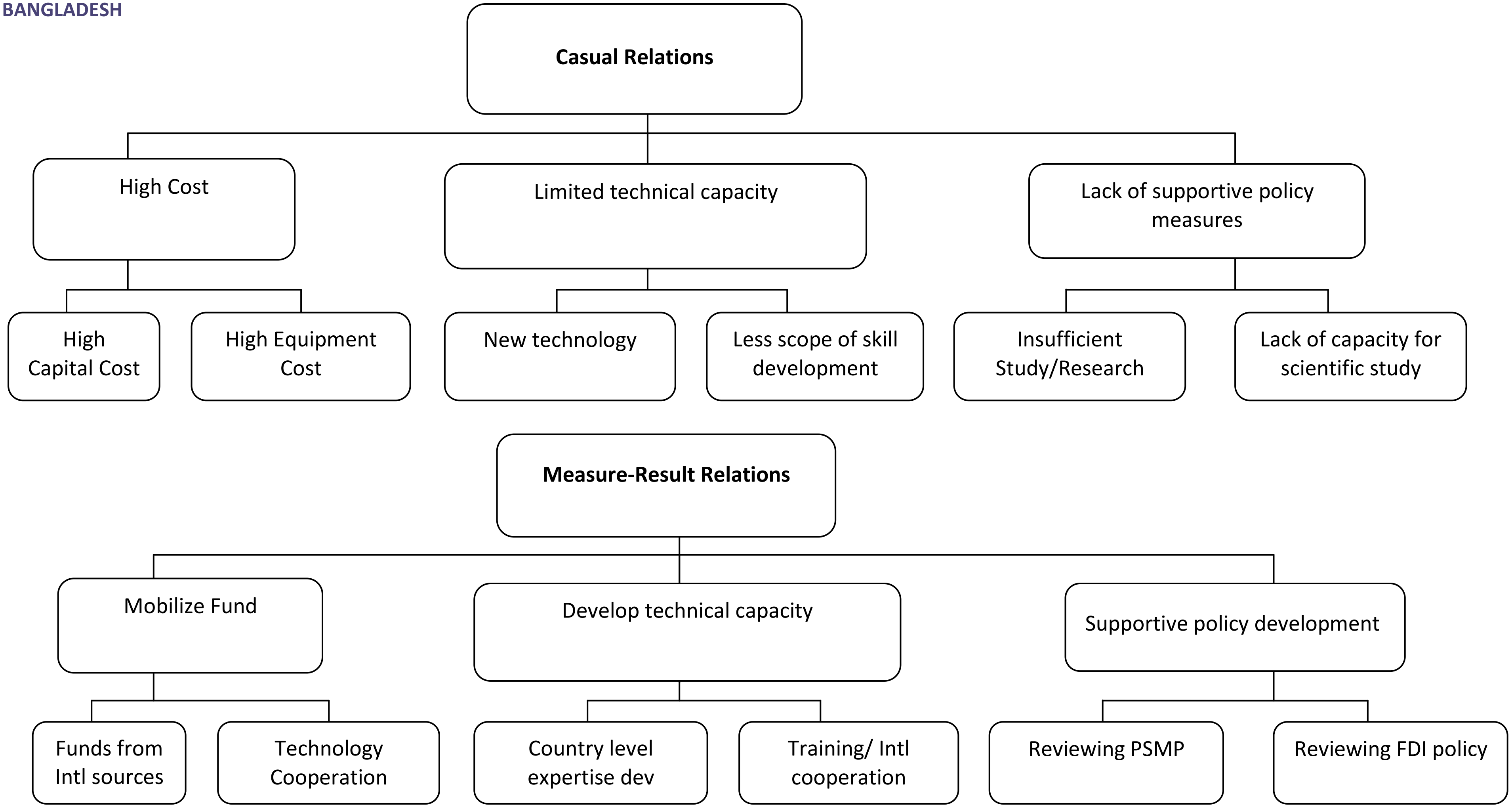

Figure 10: **Analysis of framework condition for the transfer and diffusion of Natural Gas Combine Cycle (NGCC) technology**

Annex III

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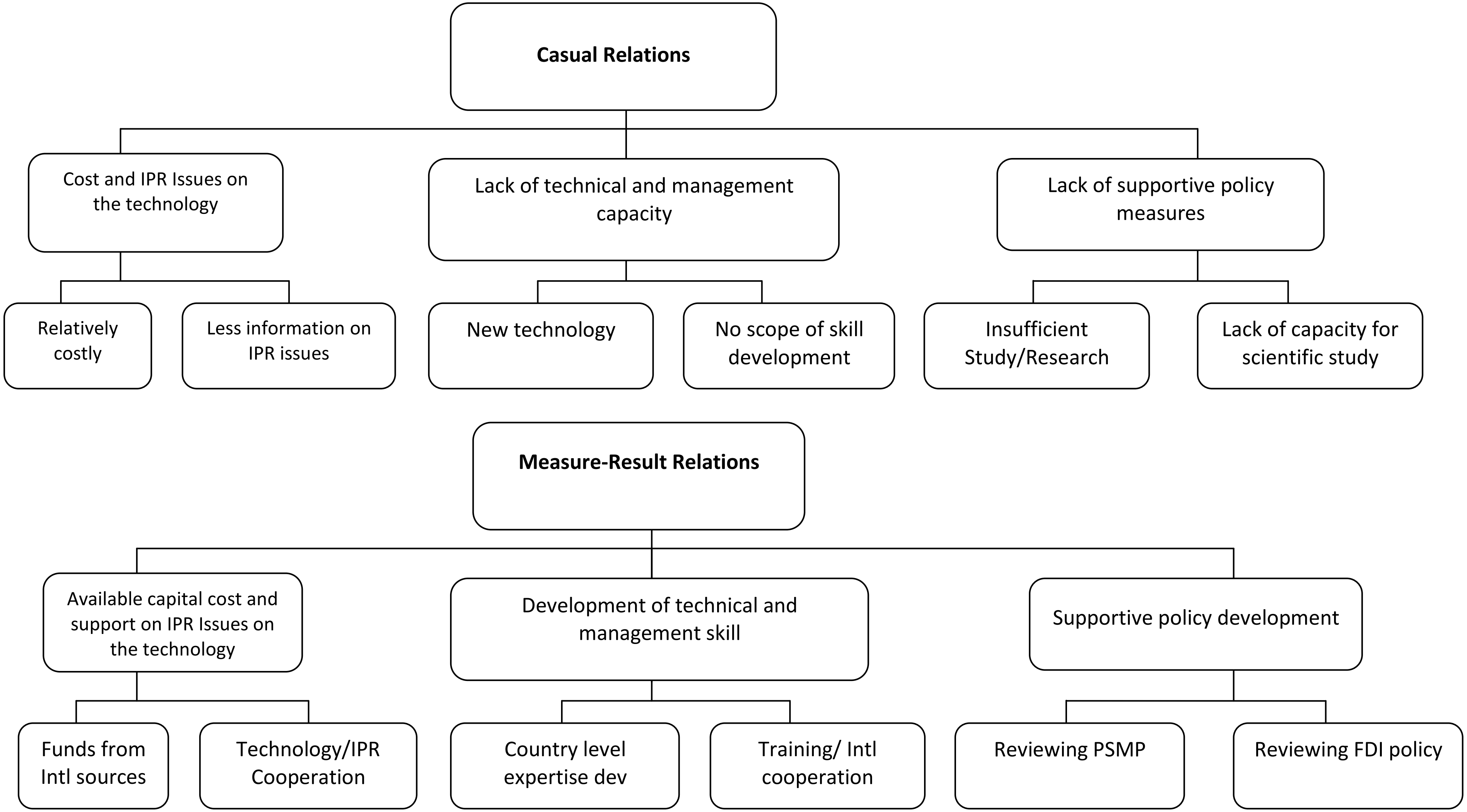

Figure 11: **Analysis of framework condition for the transfer and diffusion of Advanced Combustion Turbine Technology**

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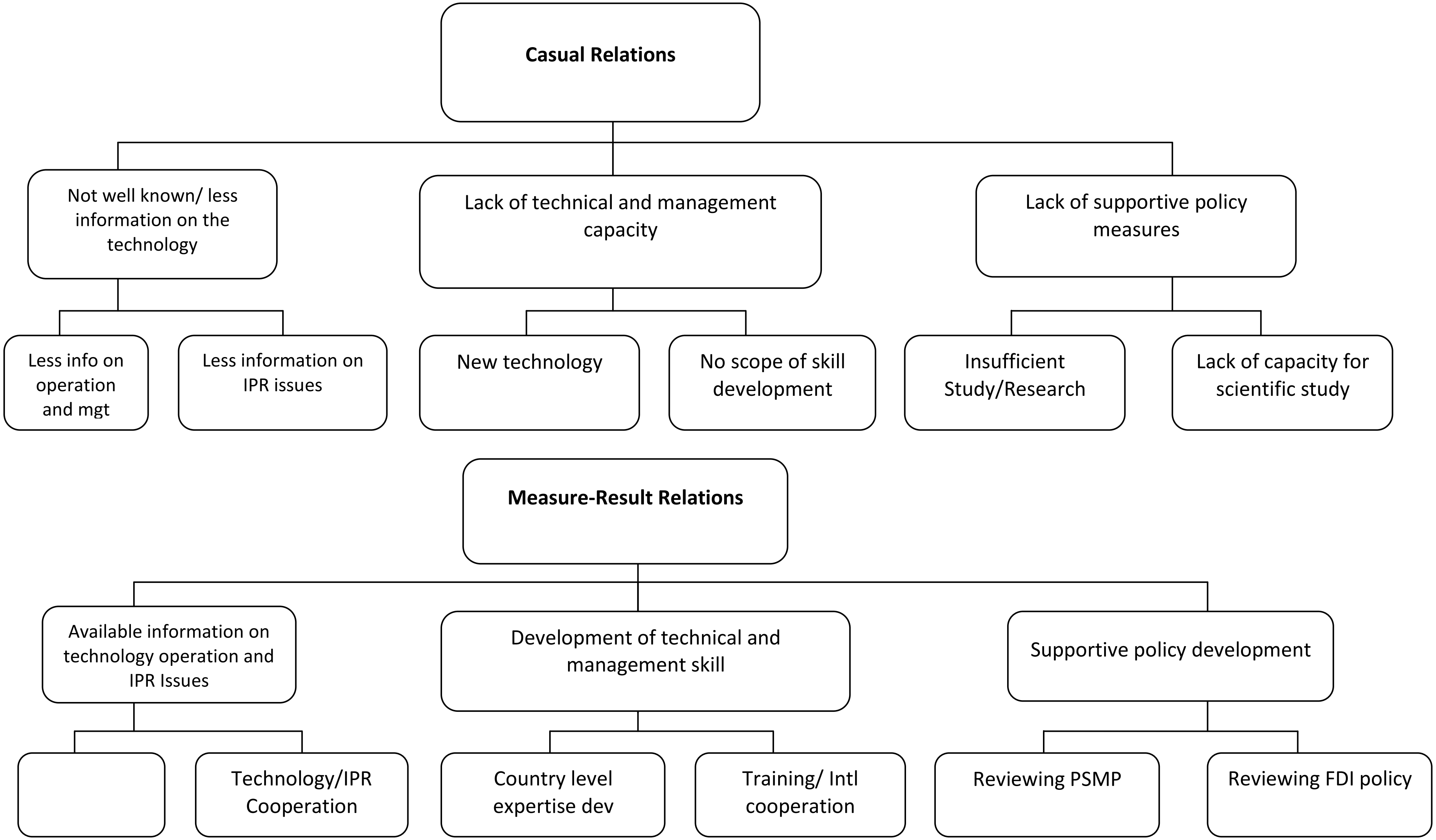

Figure 12: **Analysis of framework condition for the transfer and diffusion of Advanced Natural Gas Combined cycle (ANGCC) technology**

Annex III

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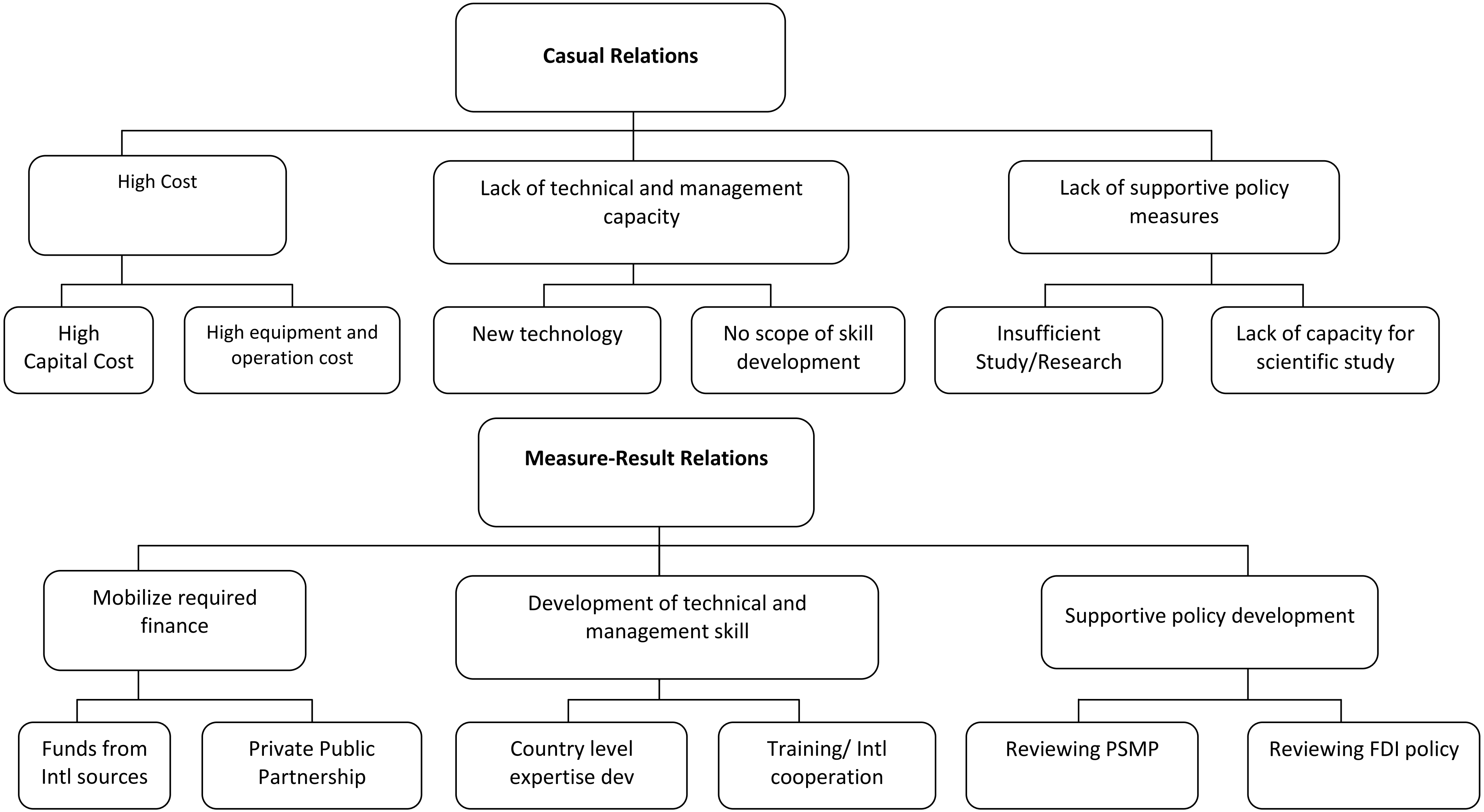

Figure 13: **Analysis of framework condition for the transfer and diffusion of Integrated Gasification Combined Cycle (IGCC) Single and Double Units Plant Technology**

Annex III

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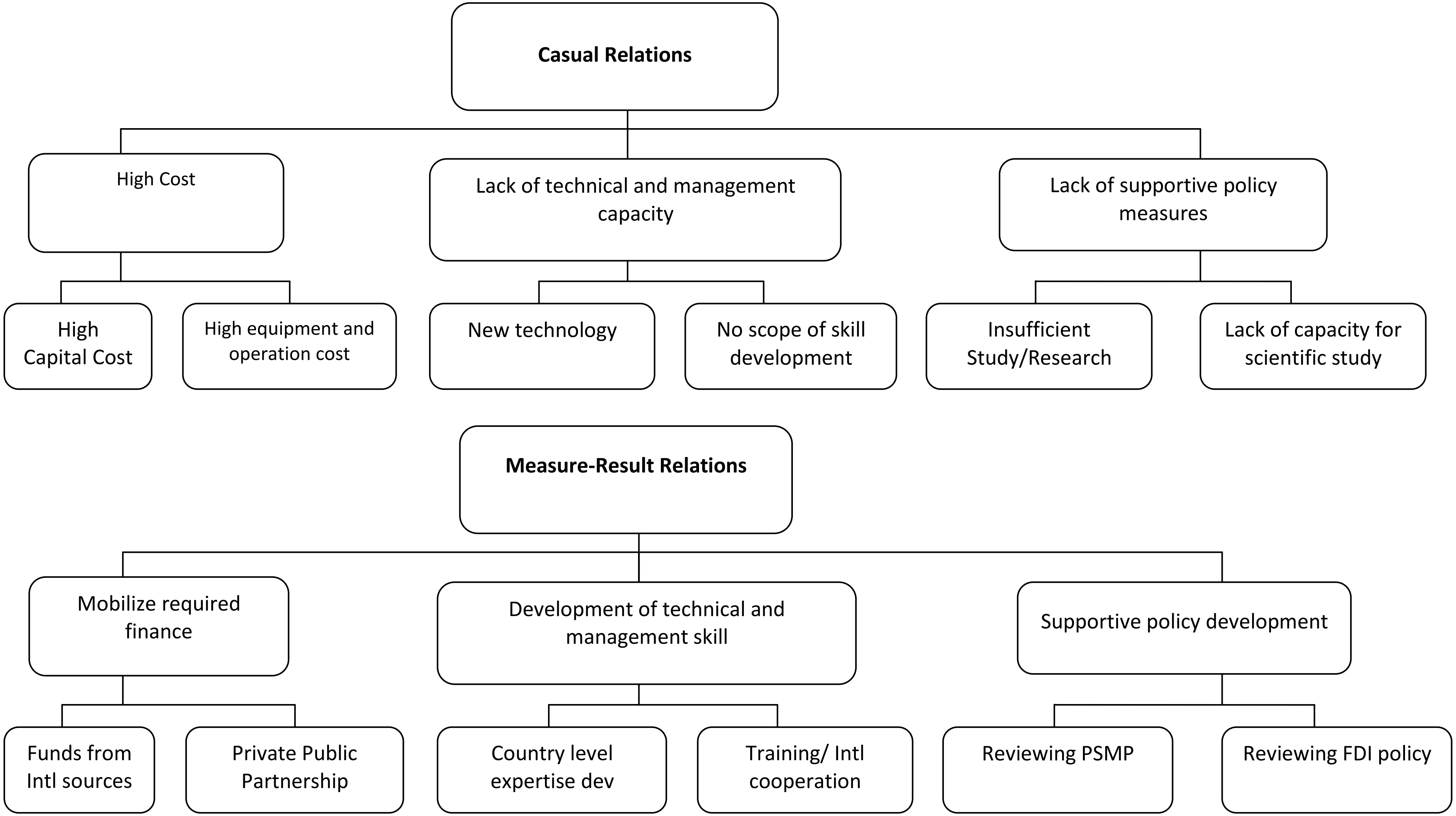

Figure 14: Analysis of framework condition for the transfer and diffusion of Advanced Pulverized Coal (APC), Single Unit and Double Unit Technology

Annex III. Project Ideas

A.1 Project Title

Installation of Advanced Pulverized Coal (Double Unit)

A.2 Introduction/Background (Briefly describe the project and how it developed):

Pulverized coal power generation starts by crushing coal into a fine powder that is fed into a boiler where it is burned to create heat. The heat produces steam that is used to spin one or more turbines to generate electricity. Subcritical plants make up the bulk of the U.S. pulverized coal system, with efficiencies for new plants usually around 37 percent. Pulverised sub-critical plants can be taken to be the benchmark for evaluating super critical, ultra super critical and IGCC plants.

Advanced Pulverized Coal Facility is provided for a nominally 650 MW coal-fired supercritical steam-electric generating unit which employs a supercritical Rankine power cycle in which coal is burned to produce steam in a boiler, which is used to run a ST to produce electric power. The steam is then condensed to water and pumped back to the boiler to be converted to steam once again to complete the cycle.

The APC double unit has the same features as for APC single unit above with the provision that the rated nominal capacity is 1300 MW. But as we shall see, not everything gets doubled including costs.

A.3 Purpose and Objectives (What will the project accomplish? What are the objectives and are they measurable? :

Major objective of Advanced Pulverized Coal (Double Unit) project is to increase power generation.

A.4 Relationship to the country's sustainable development priorities

Under sustainable development framework, the government of Bangladesh emphasizes on green growth, efficiency improvement of the energy sector etc. that will lead to reduced GHG emission. Thus, the implementation of this project will contribute to the country's strive in achieving energy security.

A.5 Project Deliverables e.g. Value/Benefits/Messages (Why it is important and necessary?):

Establishment of 1300 MW capacity Advanced Pulverized Coal (Double Unit) plant.

A.6 Project Scope and Possible Implementation (How broad is the project? How feasible is it? Is it related to current or past projects?) :

Many of the new power plants in the pipe-line are based on oil and are small as emergency measures for tackling the present shortages of electricity. One major problem had been the estimated shortage of gas. However, the present plants are very old and the same quantity of gas used in these plants can produce much more electricity using better technology. Also new discoveries and assessments of gas reserves indicate that the future supply of gas may not dwindle as fast as may have been thought so far. While new gas-based plants may be set up, clean coal technology is an attractive alternative from two points in view.
First, the country has some, though not very abundant, coal reserves. This need to be utilized well and highly efficient technologies such as IGCC may be utilized for the purpose.
Secondly, while there may be improved situation related to gas reserves, dependence on coal is likely to increase in future in which case efficient but also cleaner technologies (because coal is the dirtiest fuel from CO_2 emission point of view) needs to be employed to make the most of the scarce resource. And in that case global support leveraged by UNFCCC (in the form of Green climate funding) is likely to be available if the case is made well.

It should be noted, that out of the four coal-based power generation technology, this one is ranked 4th although there are little differences in the final scores among the prioritized technologies. More emphasis is likely to be given, under coal based generation to dual unit advanced pulverized coal technology because the investment costs are somewhat lower while the power output becomes double of that for single unit plants. In fact, one Bangladeshi coal-based plant is having a similar capacity of nearly 1300 MW.

The nominal capacity, heat rate and the emission factor that have been assumed for a Double unit plant are 1300 MW, 8,800 Btu/kwh and 206 lb of CO_2 emission per MMBtu.

A.7 Timelines (What are the timelines e.g. one quarter, one year, multiple years?) :

Multiple years

A.8 Budget/Resource requirements (What is the budget? How is the project to be funded? (Staff, Engage consultants, partnership, etc.) :

Capital Costs:
The investment cost of a double unit APC is US$ 2,844/kw. Given that the capacity of a double unit APC is 1300 MW the price tag of a double unit APC is US$ 2.844*130000 or 3.70 bn. For CT of equivalent capacity it is only US$ 1.26 bn. Going for a coal-based supercritical technology as one unit establishment, is thus going to almost 3 times costly investment compared to benchmark gas-based generation.

Operational and Maintenance Costs:

Fixed O&M: Fixed O&M costs are for double unit APC US$ 29.67 per year per kw. Thus for a double unit APC fixed cost is US$ 35.06 mn. For a CT of comparable capacity, the fixed cost becomes US$ 9.07 mn.

Variable O&M: Variable O&M for double unit APC it is 4.25/Mwh and the total comes to US$ 42.4 mn per year. For CT of equivalent power generation, the total variable O& M costs come to US$146.72 mn. Thus CT variable O& M costs are almost three times as much compared to APC double unit.

A.9 Measurement/Evaluation (What tangible evaluation of accomplishments are there?):

A.10 Possible Complications/Challenges (What are the potential challenges and complications?):

- High cost; nearly US$ 4bn for a double unit (1300 MW) plant; coals transport, and other infrastructure will raise costs further
- Present power sector master plan may need revision for emphasis on NGCC;
- Private sector foreign direct investment not allowed at the moment
- A proven but somewhat complex technology, particularly its size may lead to major managerial difficulties both technically and otherwise, regularity of supply of primary fuel may be a critical bottleneck if supply chains are not contractually spread over several years in future and proper coal handling facilities not created beforehand which will raise costs further; IPR may also be a problem
- Capacity to technologically manage such very large, modern generation unit is practically non-existent.

A.11. Responsibilities and Coordination

- Ministry of Power, Energy and Mineral Resources
- Ministry of Finance
- Ministry of Planning
- Ministry of Environment
- Bangladesh Energy Regulatory Commission
- Power Division
- Power Cell
- Bangladesh Power Development Board (BPDB)
- Power Grid Company of Bangladesh (PGCB)

The power division of the Ministry of Power, Energy and Mineral Resources will lead implementation of the project, while other institutions like Ministry of Planning and Ministry of Finance will coordinate with the development partners and private sectors for generating funds for project implementation.

Annex IV. List of stakeholders involved and their contacts

List of stakeholders of Power Generation and Use Sector

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