

National Institute of Construction Management & Research (NICMAR)

Risk Management on Ultra Mega Power Projects

*By
Abhijit Kumar Dubey*

**A Report submitted in partial fulfilment of the Academic
requirements for the Post Graduate Programme in Project
Engineering and Management
(PGP PEM)**

DECLARATION

We declare that the research thesis entitled “Risk Management in Ultra Mega Power Projects” is bonafide work carried out by us, under the guidance of Prof.Debopam Roy. Further we declare that this has not previously formed the basis of award of any degree, diploma, associate-ship or other similar degrees or diplomas, and has not been submitted anywhere else.

Date:16th March 2012.

Student's Name:
Abhijit Kumar Dubey

PGP PEM 7th Batch (2011-2013)
NICMAR Pune

CERTIFICATE

This is to certify that the research thesis entitled “Risk Management in Ultra Mega Power Projects” bonafide work of Abhijit Kumar Dubey in partial fulfilment of the academic requirements for the award of Post Graduate Programme in Project Engineering and Management (PGP PEM). This work is carried out by them, under my guidance and supervision.

Date: 16th March 2012.

Prof. Debopam Roy

Prof. P. M. Deshpande
Head, PEM

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

The Government of India is planning to develop at least nine coal-fired Ultra Mega Power Projects (UMPPs) each of 4,000 MW capacity through private competitive bidding. Three projects have already been awarded and further projects are at various stages of development. The minimum steam cycle parameters given in the Request for Proposal (RfP) from the Government of India are as follows:

- Main steam pressure = 24.7 MPa
- Main stream temperature = 535 deg C
- Reheat stream temperature = 565 deg C

Taking these parameters into account project developers are expected to utilize supercritical rather than the subcritical technology currently prevalent in India.

While the application of supercritical technologies using the above steam cycle parameters will lead to lower carbon dioxide (CO₂) emissions than would the use of subcritical technologies, there is an opportunity for the bidders to move further up the technology ladder. By using further elevated steam cycle parameters bidders could apply advanced supercritical technology for new coal-fired power plants, thus reducing CO₂ emissions further and reducing India's contribution to climate change.

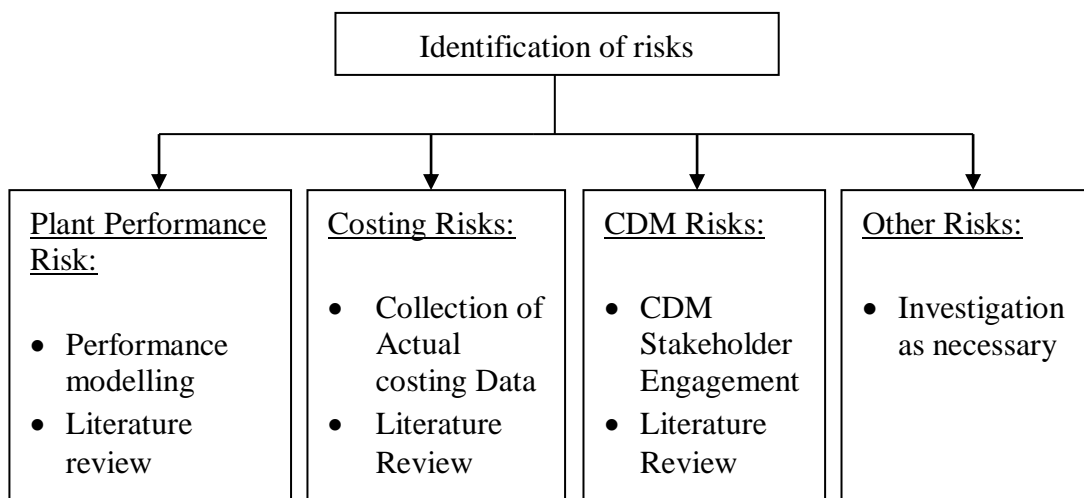
2.0 OBJECTIVES

The key objectives of the present study are as follows:

- To identify and investigate the range of real and perceived risks associated with the deployment of advanced coal technologies in the Indian power market.
- To investigate the latest developments in the carbon markets and identify sources of finance available to UMPP bidders to overcome barriers in India to the implementation of advanced coal technologies.
- To update the techno-economic model for the first study to reflect the above investigations and so more accurately explore the techno-economic feasibility of deploying more advanced coal technologies for the UMPPs given access to revenues from carbon finance.
- To present the case to industry (the UMPPs bidders) to encourage them to adopt the 'best available technologies' when developing the UMPPs.

3.0 APPROACH

The Figure below illustrates how the strands of investigation combine to allow conclusions to be drawn:



4.0 Risk Investigations

4.1 Plant Performance Risks

Concerned issues of plant performance risk are impact of Indian ambient conditions and the use of Indian coals on advanced supercritical plant with regard to availability and plant performance (efficiency).

4.1.1 Indian Conditions

Indian ambient conditions and grid infrastructure capability must be considered when designing a supercritical plant for use in India:

- High ambient temperatures lead to a low achievable condenser pressure vacuum and high steam consumption which may lead to boiler overloading. These issues can be addressed by designing the boiler with additional margin to meet with low vacuum and high demand steam requirements. These together with high relative humidity, which leads to more losses in cooling tower, lower the overall plant efficiency.
- Poor grid stability leads to a high variation in grid frequency which may lead to low fluctuations and more forced outages. This issue can be mitigated by; increasing margin in boiler design to take care of fluctuations and number of outages, by utilizing high capacity (60%) HP/LP bypass to keep boiler on load in case of emergencies and by using modern control system (unit master control) to cope with grid fluctuations.

4.1.2 Indian Coals

The high ash and silica content of Indian coals and their low CV value must be considered when designing a supercritical plant for use in India because they may impact reliability and they will reduce boiler efficiency:

- The high ash and silica content of Indian coals could lead to high erosion of the boiler tubes. By controlling the flue gas velocity to less than 10m/s and installing tube shields erosion can be reduced to international standards. Implementing the latest developments in Computational Fluid Dynamics (CFD) modeling and developments in the tower design boilers can reduce erosion to acceptable levels.
- Due to low CV and high ash content the amount of Indian coal required to produce the heat output is high in comparison to imported coals. This will lead to a high furnace volume and require larger milling and ash handling power. This may lead to greater risk of outage of auxiliary equipment and to partial load operation. To mitigate these risks standby systems for coal handling and milling plants should be appropriately designed and the latest developments in new ceramic and high chrome materials should be implemented to maintain reliability.
- The low CV value of Indian coals will also lead to lower boiler efficiency. To mitigate this impact high volume furnaces and better boiler tube material with more design margins need to be considered.
- Indian coal typically has high moisture content. This will lead to lower boiler efficiencies for plant burning Indian coal compared to those firing better quality coals.
- Low volatile matter and low ash fusion temperature in Indian coal will lead to high unburnt carbon losses. These issues can be mitigated by utilizing a higher capacity milling system to achieve better coal thinness and more retention time in the boiler.
- High ash coal handling costs, due to high ash proportion, and increased milling power demand lead to higher auxiliary power consumption for plants burning Indian coals.

The Table below shows details of Unit Size, Main Steam Pressure, Main Steam temperature and Reheat Steam Temperature for Subcritical, Low Supercritical, High Supercritical and Ultra supercritical plant Types:

Plant Type	Unit Size	Main Steam Pressure	Main Steam Temperature	Reheat Steam Temperature	Notes
Subcritical	500MW	16.6MPa	538° C	538° C	Common Practice in India
Low Supercritical	660MW	24.7MPa	538° C	565° C	India's first supercritical station at Sipat and minimum conditions stipulated in UMPP RFP
High supercritical	800MW	27.0MPa	565° C	593° C	Suspected Parameters of India's first Ultra Mega Power Project proposed at Mundra
Ultra supercritical	1000MW	29.5MPa	600° C	600° C	Ultra super Critical Plant operated in Japan.

Source: British High Commision New Delhi- UMPP risk analysis.

The efficiency of supercritical plants using Indian coal is lower than that using international coal but the difference is less than expected due to the impact of Indian conditions (see table below).

Efficiency	Subcritical	Low supercritical	High supercritical	Ultra supercritical
Indian coal (under Indian conditions)				
Unit net efficiency, LHV	38.12%	39.35%	40.43%	42.28%
Unit net efficiency, HHV	36.18%	37.35%	38.38%	40.13%
International coal (under Indian conditions)				
Unit net efficiency, LHV	38.45%	39.69%	40.78%	42.64%
Unit net efficiency, HHV	37.02%	38.21%	39.26%	41.05%

Source: British High Commission New Delhi- UMPP risk analysis.

4.2 Costing Risks

Concerned issues are about the economics of advanced supercritical plant (especially given current market demand and the limited number of suppliers). Issues are also about the impacts on plant economics of Indian ambient conditions and coals and extra costs due to lack of local experience and capability in advanced technologies.

The risks identified have been incorporated into a costing exercise to estimate capital and operational and maintenance costs for a 4000 MW plant for each of the technologies under consideration firing Indian and international coals as follows:

- Higher advanced supercritical capital costs. The increased capital costs of boilers, steam turbines and auxiliaries associated with advanced coal technologies is reflected in the capital costs used in the costing exercise.
- Higher advanced supercritical O&M costs. While some O&M costs reduce as a move is made up the technology ladder, others such as; staff costs, spare parts and maintenance (routine), and chemicals/oils/consumables increase. These extra costs are reflected in the costing exercise.
- Limited number of suppliers of advanced plant. Costing is based on actual ordered costs for projects under development and thus reflects market pricing.
- Lack of local advanced supercritical experience/manufacturing capability. Costing assume that original equipment manufacturers will provide training, be involved in commissioning activities and provide long term service

agreements. Extra staff costs for advanced technologies have also been included to reflect higher staff and training costs.

- Although Indian coal has a high silica content that could increase maintenance requirements, proper plant design and the application of mitigation measures, is expected to minimise potential negative maintenance impacts of firing Indian coals. Consequently maintenance costs are assumed constant across coal types.
- The low CV value of Indian coals means that boilers designed to fire Indian coal will need to have a bigger furnace volume and thus will require bigger boilers. These larger boilers will increase capital costs for plants burning Indian coal compared to those burning international coal. Although advanced plants utilise exotic and expensive metals these are utilised in the boiler tubes rather than the furnace itself and thus the impact of firing Indian coals on boiler and auxiliary costs is limited to marginal increases.
- As boiler size increases balance of plant requirements and costs also increase. Thus plants burning Indian coal have higher balance of plant costs than those burning international coals.
- This cost difference is mitigated somewhat due to increases in other balance of plant costs, such as seawater cooling and piling requirements, associated with locating plants on the coast.
- The high ash content of Indian coals will increase ash handling costs in plants burning Indian rather than international coals. This impact is reflected in the ash disposal costs in the costing exercise.
- International coals can have higher sulphur content than Indian coals and thus plants burning international coals could, in the future, require the installation of FGD (Flue Gas Desulphurisation) plant .

4.3 CDM Risks

CDM (Clean Development Mechanism-One of the three flexible mechanisms in Kyoto Protocol).

The main CDM risks identified and the way such risks have been dealt with in the study are summarised below:

- **Baseline applicability:** Since an applicable methodology (ACM0013) has been approved for projects utilising advanced coal technologies the risks associated with methodology approval have now been mitigated. Also, additionality can be shown using a barrier analysis as no advanced supercritical power plants are yet operational in India. This demonstrates the real uniqueness of the project. The technology has achieved very limited penetration in India due to investment, technology and other barriers.

- **Transaction costs.** CDM transaction costs will be very small compared to the overall costs of UMPP projects and compared to the value of CERs(Certified Emission Reductions-a unit of emission) from any approved CDM project.
- **Post 2012 rule changes.** The agreed compliance period of the Kyoto Protocol expires at the end of 2012, and the Parties to the UNFCCC and Kyoto Protocol have not yet agreed on a new framework to succeed the Kyoto Protocol, which results in large uncertainty with regards to the period Post-2012. As a result of forthcoming negotiations, India could be affected by a post-2012 agreement, but the shape of this agreement is not known yet. In the next two years, it will become clearer how a treaty post-2012 will impact on India and its post-2012 CDM market, which also depends on India's negotiation position in the coming years.
- Projects registered as CDM projects pre 2012 should not be affected, and even though the political path is uncertain there is significant interest in the carbon community for post 2012 CERs.

4.4 Other Risks

Infrastructure risk with special regard to transportation is another risk that needs to be considered. This infrastructure risk is especially pertinent to high and ultra supercritical technologies which use bigger unit sizes with larger and heavier associated parts. Delays due to transport issues and /or associated costs of upgrading infrastructure (i.e. roads) could be considerable.

Conclusions

- This study has identified and quantified the key risks for UMPP relating to deploying advanced supercritical coal plants within the Indian market. These risks can be grouped into three main categories:
 - plant performance under Indian conditions
 - economic viability of advanced technologies
 - post 2012 CER value.
- Consideration of the risks above has the effect of:
 - increasing plant costs compared to international plants located in more favourable climatic conditions
 - increasing the costs associated with the more advanced technologies compared to the less advanced options.

CHAPTER 2 PLANT PERFORMANCE RISKS

2.1 INTRODUCTION

The concerned issues are the impact of Indian ambient conditions and the use of Indian coals on advanced supercritical plant:

- Availability
- Plant performance – efficiency.

2.2 AVAILABILITY OF ADVANCED COAL PLANTS

2.2.1 THE INTERNATIONAL PERSPECTIVE

When advanced coal technologies were first introduced in the 1960s the technology suffered from lower availability than subcritical plant due largely to reliability issues in the boiler including tube leaks and waterwall tube cracks. However, as the technology has matured these issues have been addressed. New manufacturing techniques, improved welding procedures and an improved understanding of advanced materials have improved quality control leading to improved reliability and availability. There are now over 500 supercritical plants in operation worldwide and the current literature indicates that the reliability and availability of new supercritical units is expected to be equivalent to subcritical units.

Operational data from the Japan Electric Power Information Centre (JEPIC), Federation of Electric Power Companies of Japan (FEPC) and the Electric Power Development Company (EPDC), all support the conclusion that in the international context modern supercritical plants now have a similar availability and reliability to subcritical plants.

2.2.1.1 SUPERCRITICAL TECHNOLOGY CONSIDERATIONS

Supercritical boilers are designed for higher steam temperatures and pressures than subcritical boilers and also operate using a once-through evaporator. Designers and owners have to be aware of certain issues in order to reduce technical risks to an acceptable level. These include:

- Waterwall cracking
- Negative flow characteristic
- Slagging.

There is no reason to believe that all of these risks will appear in every project. However, there remain some risks that should be addressed during design and operation of the plant.

Waterwall Cracking

Thermal fatigue cracking of waterwall tubes is believed to be the leading cause of tube failures in supercritical boilers. It is not clear why supercritical boilers are more susceptible to this type of cracking than subcritical boilers, however possible reasons include higher metal temperatures and the use of low alloy steel. Thermal fatigue cracking is caused by the combined action of elevated metal temperatures and thermal cycling. Elevated metal temperatures may be caused by the growth of internal tube deposits, high heat flux, and deterioration of fluid-side cooling or external fire-side coatings. Thermal cycling may be caused by slagging and shedding, sootblowing, water cleaning or other factors. Fire-side corrosion is also believed to be a contributing factor to thermal fatigue cracking. The use of oxygenated water treatment may reduce the risk of waterwall cracking.

This phenomenon is currently under investigation by various organizations and supercritical plant owners and operators should be aware of this problem, which represents a potential risk to plant availability.

Negative Flow Characteristic

Most modern supercritical boilers operate using sliding pressure. When the boiler is operating at partload the pressure is subcritical and the furnace acts as a once through evaporator. This design requires a high mass flux through the tubes to avoid departure from nucleate boiling (DNB) and subsequent overheating of the tube metal. A high mass flux design has an undesirable feature referred to as a negative flow characteristic. This feature causes tubes that experience higher than average heating to draw lower than average fluid flow. Subcritical boilers that operate using natural circulation have a positive flow characteristic whereby tubes that experience higher than average heating tend to draw higher than average fluid flow.

If the furnace heat flux distribution is non-uniform due to slagging or other factors, the negative flow characteristic can lead to a non-uniform fluid temperature profile and high fluid temperatures at the outlet of the waterwalls. This can result in possible overheating of tubes in the upper furnace, DNB at high heat flux areas and differential thermal expansion of the waterwalls.

Some supercritical boiler suppliers are now offering low mass flux designs with internally rifled tubing to overcome this problem.

Slagging

Supercritical boilers are typically designed with a spiral tube configuration in the furnace to produce a high fluid mass flux in the tubes. The spiral configuration requires the tubes to be installed at an inclined angle typically between 10 to 15 degrees from the horizontal. The inclination of the tubes is thought to increase the propensity of slag and clinker to form on the waterwalls compared to vertical tubing, which is typically used in subcritical boilers. The higher fireside metal temperatures of supercritical boilers may also contribute to increased slagging.

The risk issues stated above are observed in some supercritical plants. In order to mitigate these risks, the following aspects need to be considered in the design and operation of the plant:

- use of oxygenated water chemistry
- use of non-slagging coal in the boiler
- selection of coal to avoid fire-side corrosion
- consideration of rifled furnace tubes and possibly vertical tube furnaces with rifled tubing.

2.2.2 FIRING INDIAN COAL AND IN INDIAN CONDITIONS

While advanced plants may have similar availability to subcritical plants under international conditions Indian ambient conditions and the use of Indian coals demand a number of issues to be dealt with to ensure reliability and availability of Indian plants remains high. These issues and mitigation measures are dealt with briefly below.

(i) Indian Coals

The high ash and silica content of Indian coals and their low CV value must be considered when designing a supercritical plant for use in India:

- The high ash and silica content of Indian coals could lead to high erosion of the boiler tubes. The ash fusion temperature of Indian coal is roughly 1,350-1,400 oC this could lead to high ash deposition on the high temperature boiler tubes and reduce the heat transfer efficiency which could lead to high boiler tube leakages. By controlling the flue gas velocity to less than 10m/s and installing tube shields, erosion can be reduced to international standards. Implementing the latest developments in Computational Fluid Dynamics (CFD) modeling and developments in the tower design boilers can reduce erosion to acceptable levels.
- Due to low CV and high ash content the amount of Indian coal required to produce the heat output is high in comparison to imported coals. This will lead to a high furnace volume and require larger milling and ash handling power. This may lead to greater risk of outage of auxiliary equipment and lead to partial load operation. To mitigate these risks standby systems for coal handling and milling plants should be appropriately designed and the latest developments in new ceramic and high chrome materials should be implemented to maintain reliability.

(ii) Indian Conditions

Indian ambient conditions and grid infrastructure capability must be considered when designing a supercritical plant for use in India:

- High ambient temperatures lead to a low achievable condenser pressure vacuum and high steam consumption which may lead to boiler overloading.

These issues can be addressed by designing the boiler with additional margin to meet with low vacuum and high demand steam requirements.

- **Poor grid stability** leads to a high variation in grid frequency which may lead to low fluctuations and more forced outages. This issue can be mitigated by; increasing margin in boiler design to take care of fluctuations and number of outages, by utilising high capacity (60%) HP/LP bypass to keep boiler on load in case of emergencies and by using modern control system (unit master control) to cope with grid fluctuations.

By implementing the above mitigation strategies the average availability of advanced supercritical power plants in India is expected to be similar to those seen worldwide and thus comparable to subcritical plants.

2.3 EFFICIENCY

2.3.1 THE INTERNATIONAL PERSPECTIVE

Table 2-2 Illustrates the efficiencies achieved at international supercritical plant in operation with various steam cycle parameters.

TABLE 2-2

Steam cycle parameters	Plant									
		1	2	3	4	5	6	7	8	9
Steam pressure	MPa	25	25	25	25	25	30	30	30	30
Mainsteam temp	°C	530	530	540	540	540	540	540	580	580
Reheater steam temp	°C	540	540	560	560	560	560	560	600	600
Net efficiency, HHV	%	41	41.2	41.5	41.6	42.5	42.6	42.8	43.7	44.3
Incremental improvement	%	0	0.5	0.8	0.25	2	0.3	0.5	2	1.3

Note: the numbering corresponds to different plants operating around the world

Source: STEAG encotec

Although high efficiencies have been achieved internationally Indian ambient conditions and the firing of Indian coals will act to reduce the efficiencies that are realistically achievable in India. These issues are discussed below:

2.3.2 FIRING INDIAN COAL AND IN INDIAN CONDITIONS

2.3.2.1 INDIAN COALS

The high ash and silica content of Indian coals and their low CV value will impact efficiencies achievable in Indian advanced coal plant. The following issues must be considered:

- Indian coal can have higher moisture content than imported coals (see Table 2-4 and Table 2-5). This will lead to lower boiler efficiencies for plant burning Indian coal compared to those firing better quality coals. While the utilization of water cannons in place of steam to achieve a better clean surface and smart soot blowing system with online performance optimization can mitigate these impacts boiler efficiencies for plant burning Indian coal will still be lower than those burning international coal. This has been reflected in the plant performance modeling undertaken in the following section.
- Indian coal can have Low volatile matter and low ash fusion temperatures can lead to high unburnt carbon losses. These issues can be mitigated by utilizing a higher capacity milling system to achieve better coal thinness and more retention time in the boiler.
- The low CV value of Indian coals will necessarily lead to lower boiler efficiency. To mitigate this impact high volume furnaces and better boiler tube material with more design margins need to be considered. This has been reflected in the plant performance modeling undertaken in the following section.
- High ash coal handling costs, due to high ash proportion, and increased milling power demand lead to higher auxiliary power consumption for plants burning Indian coals.

2.3.2.2 INDIAN AMBIENT CONDITIONS

The high ash and silica content of Indian coals and their low CV value will impact efficiencies achievable in Indian advanced coal plant in the following ways:

- High ambient temperature leads to high cooling water temperatures which, based upon operational data from Indian plants, reduces the achievable condenser vacuum to a maximum of 0.13 bar a. This leads to a high steam consumption and low turbine heat rate.
- High relative humidity leads to more losses in cooling tower.

2.3.3 COAL ANALYSIS

Pit head projects were fired from Singrauli coal from India while coastal projects were fired from international coal represented by Mount Arthur coals.

The typical proximate and ultimate analysis are given in Table 2-4 and Table 2-5 below.

TABLE 2-4: TYPICAL PROXIMATE ANALYSES FOR SINGRAULI AND MOUNT ARTHUR COALS

Item	Unit	Singrauli Coal	Mount Arthur Coal
Fixed carbon	%	34.50	51.50
Volatile matter	%	20.00	33.00
Moisture	%	9.55	3.50
Ash	%	40.00	12.00
Grindability Index	HGI	50.00	50.00
Higher heating value	kCal/kg	3,667.09	6,320.00
Higher heating value	MJ/kg	15.35	26.46
Lower heating value	MJ/kg	14.52	25.32

Source :

1. Singrauli Coal Fields, Data sourced from slide 30 of 33 of a presentation titled, “ 4000 MW Ultra Mega Power Project, Sasan, India”.
2. Steam coal from Mount Arthur, Australia, Data sourced from chapter 7 of “McCloskey’s Big Coal Book 2002”.

TABLE 2-5: TYPICAL ULTIMATE ANALYSES FOR SINGRAULI AND MOUNT ARTHUR COALS

Item	Unit	Singrauli Coal	Mount Arthur Coal
Carbon	%	38.7	69.29
Oxygen	%	8.67	8.20
Sulphur	%	0.50	0.70
Hydrogen	%	2.61	4.63
Nitrogen	%	0.75	1.69
Water	%	9.38	3.50
Ash	%	39.39	11.99
Sum of all constituents	%	100.00	100.00

Source :

1. Singrauli Coal Fields, Data sourced from slide 30 of 33 of a presentation titled, “ 4000 MW Ultra Mega Power Project, Sasan, India”.
2. Steam coal from Mount Arthur, Australia, Data sourced from chapter 7 of “McCloskey’s Big Coal Book 2002”.

2.3.4 AMBIENT CONDITIONS

The selection of design ambient conditions was based upon the meteorological conditions at the Sasan UMPP site shown in Table 2-6(on next page). These parameters are assumed to be constant for pit head and coastal sites.

TABLE 2-6: COMMON AMBIENT CONDITIONS

Item	Unit	Site conditions
Mean daily maximum temperature (January)	°C	24.3
Mean daily minimum temperature (January)	°C	8.1
Mean daily maximum temperature (May)	°C	42.0
Mean daily minimum temperature (May)	°C	25.8
Average RH during morning	%	66%
Average RH during evening	%	49%
Site elevation	M	280

Source : Meteorological conditions sourced from slide 28 of 33 of a presentation titled, “4,000 MW Ultra Mega Power Project, Sasan, India”.

CHAPTER 3 COSTING RISKS

3.1 INTRODUCTION

Concerned issue is about the economics of advanced supercritical plant (especially given current market demand and the limited number of suppliers), there are also other issues over the impacts on plant economics of Indian ambient conditions and coals and extra costs due to lack of local experience and capability in advanced technologies.

The risks identified have been incorporated into a costing exercise to estimate capital and operational and maintenance costs for a 4,000 MW plant for each of the technologies under consideration firing Indian and international coals.

3.2 INCORPORATION OF RISKS HIGHLIGHTED

The incorporation into the costing exercise of the risks identified is discussed below:

1. High advanced supercritical costs

- **Higher advanced supercritical capital costs:** The increased capital costs of boilers, steam turbines and auxiliaries associated with advanced coal technologies is reflected in the capital costs used in the costing exercise.
- **Higher advanced supercritical O&M costs:** While some O&M costs reduce as a move is made up the technology ladder, others such as staff costs, spare parts and maintenance (routine), and chemicals/oils/consumables increase. These extra costs are reflected in the costing exercise.
- **Limited number of suppliers of advanced plant:** Costing are based on actual ordered costs for projects under development and thus reflect market pricing – including any impact on the prices due to constrained competition or high market demand when the orders were placed. We recognize that costs reflect market conditions when the orders were placed rather than market conditions today.
- **Lack of local advanced supercritical experience/manufacturing capability:** Costing assume that original equipment manufacturers will provide training, be involved in commissioning activities and provide long term service agreements. Extra staff costs for advanced technologies have also been included to reflect higher staff and training costs.

2. Coal Quality

- Although Indian coal has a **high silica content** that could increase maintenance requirements, proper plant design and the application of mitigation measures, including the control of flue gas velocity, is expected to minimize potential negative maintenance impacts of firing Indian coals. Consequently maintenance costs are assumed constant across coal types.
- The **low CV value** of Indian coals means that boilers designed to fire Indian coal will need to have a bigger furnace volume and thus will require bigger boilers. These larger boilers will increase capital costs for plants burning Indian coal compared to those burning international coal. Although advanced plants utilize exotic and expensive metals these are utilized in the boiler tubes and first stage HP/IP turbine blades rather than the furnace itself and thus the impact of firing Indian coals on boiler and auxiliary costs is limited to marginal increases.

As boiler size increases balance of plant requirements and costs also increase. Thus plants burning Indian coal have higher balance of plant costs than those burning international coals. This cost difference is mitigated somewhat due to increases in other balance of plant costs, such as seawater cooling and piling requirements, associated with locating plants on the coast.

These extra costs are reflected in the costing exercise.

- The **high ash content** of Indian coals will increase ash handling costs in plants burning Indian rather than international coals. This impact is reflected in the ash disposal costs in the costing exercise.
- International coals can have higher sulphur content than Indian coals and thus plants burning international coals could, in the future, require the installation of **FGD plant**. Since there is no requirement under the RFP to include FGD in the current UMPP developments and given that bidders expect a tariff renegotiation should FGD become mandatory FGD costs have not been included in the analysis.

3.0 CAPITAL COSTS

India has an embryonic but expanding local supercritical plant and spares manufacturing capability based on partnerships with international suppliers. As yet there are no announced plans for the development of a local manufacturing capacity in advanced supercritical technologies. This absence of local advanced supercritical manufacturing capability means that a developer who wishes to employ this technology in the Indian market will be wholly dependent upon international suppliers and will face the risks and potential associated impact on capital and O&M costs.

- Since no ultra supercritical project has been developed in India the costings would have to be based upon discussions with plant suppliers and similar projects which can be carried out in the latter part of the study to reflect Indian conditions.
- Some variable costs identified are listed below:
 - Boiler & auxiliaries
 - Steam turbine generator & auxiliaries
 - Electrical Equipment
 - Plant control system
 - Balance of plant
 - Buildings & common structures
 - Site preparation, roads and general infrastructure
 - Land costs
 - EPC contractor engineering & management
 - Spares, tools & training
- Site accommodation capital costs are scaled in proportion to the increase in staff numbers when moving from a single unit to a 4,000 MW plant.
- Subcritical plant is manufactured in India, with local Indian labour used for the construction.
- Supercritical plant is imported to India from overseas, with local Indian labour used for the construction.
- The terminal points for the Engineer Procure and Construct (EPC) contract are as follows:
 - Coal: power station coal stockpile (including stockpile)
 - Raw water and cooling water: power station plant boundary
 - Electricity: HV terminals of generator transformer
 - Ash: outlet of ash silo

- Effluent: power station plant boundary.
- The EPC or owner's costs are based on:
 - EPC contractor engineering and management
 - Spares, tools and training
 - Site accommodation for dwellings
 - Insurance
 - Owner's engineer and approvals
 - Owner's contingency.

4.0 Operations and Maintenance Costs

The following major components have been assumed to contribute to the plant fixed and variable O&M costs:

Fixed Costs

- Staff
- Insurance charges/fees
- Service contracts (canteen services, site security services, grounds and building maintenance, cleaning services, consultants), overheads, license fees.
- Contract scheduled maintenance
- Administration costs

Variable Costs

- Spare parts and routine maintenance
- Chemicals/oils/consumables
- Water make-up cost
- Sewage disposal

- Ash disposal
- Spare parts and maintenance (routine)

Fuel costs have been excluded from the variable O&M costs analysis.

Major infrastructure costs, such as road and bridge upgrading, beyond the site boundary, costs associated with ensuring grid stability and the impact of engineering in seismically active areas have been assumed as exogenous to developer costs and thus have been excluded.

CHAPTER 4

CDM RISKS

4.1 Introduction

The Clean Development Mechanism (CDM) is one of the three flexible mechanisms under the Kyoto Protocol. Article 12 of the Kyoto Protocol lays out the CDM in more detail. The purpose of the CDM is twofold. First, it should give the opportunity to reduce emissions where it is economically cheapest and thus reducing the costs for the developed countries (Annex-I countries) to meet their obligation and second to support sustainable development in the developing countries (non-Annex-I countries).

The CDM is a project based mechanism. Annex-I countries, which have emission caps, assist non-Annex-I countries in implementing a project that reduces greenhouse gas emissions below their baseline emissions. For each verified ton of CO₂ equivalent reduced in a non-Annex-I country, a Certified Emission Reduction (CER) is issued. A CER can be sold to Annex-I countries. CERs bought by an Annex-I country will be added to the assigned amount units of emissions of an Annex-I country, therefore allowing this country to comply with its Kyoto commitments.

The CDM provides a mechanism for non-Annex-I countries to implement cleaner technology, which they would not have undertaken without the CER revenue, due to financial unattractiveness. The perspective of earning CERs, which can be sold on the market, can be attractive to investors and/or developers. Investors can get a return on their money and project developers can move a step up the technology ladder. A CDM project always needs to be additional, which means that emission reductions would not have occurred in absence of the project activity.

Showing additionality of a project is the main task for registering a project. CDM projects need to be registered with the Executive Board (EB) of the United Nations Framework Convention on Climate Change (UNFCCC). Before registration each project need to be validated through an external entity and receive letters from the Designated National Authority (DNA) of each country participating in the project, During the lifetime of the project, emissions need to be monitored and verified by an independent entity before CERs will be issued.

The whole project cycle of the CDM includes transaction costs. These costs arise mainly due to external validation and verification, registration fees and CER issuance fees. Transaction costs can decrease the amount of CERs available or lead to the favouring of certain project types. Transaction costs make the overall mitigation effort under the Kyoto Protocol more expensive and bias the portfolio of projects towards large-scale projects.

4.2 Efficient Coal Technologies and the CDM

In order to develop a CDM project and have it registered a project developer needs to follow a certain methodology. Methodologies need to be registered with, and approved by the CDM Executive Board. At the moment 126 methodologies are approved for numerous kinds of projects. In case a CDM project is being developed and none of the existing methodologies is applicable, a new methodology needs to be written and approved by the Executive Board.

4.2.1 CDM Transaction Costs

Since an applicable methodology has already been approved for projects utilising advanced coal technologies the risks associated with Methodology approval have now been mitigated as have some of the transaction costs associated with the CDM process.

4.2.2 Methodology Status

At the end of January 2007 two new methodologies for large scale fossil fuel power plant were submitted to the UNFCCC for approval, one of them from a Chinese Project Developer (NM0215) and the other one from an Indian Project Developer (NM0217).

The proposed new methodologies shared common elements and have been merged into a single approved consolidated baseline and monitoring methodology - ACM0013.

The new methodology can only be used for new electricity generation projects and is applicable under the following conditions:

- The project activity is the construction and operation of a new fossil fuel fired grid-connected electricity generation plant that uses a more efficient power generation technology (a possible project activity could be, e.g., the construction and operation of a supercritical coal-fired power plant) than what would otherwise be used with the given fossil fuel.
- The project activity is not a co-generation power plant.
- Data on fuel consumption and electricity generation of recently constructed power plants is available.
- The identified baseline fuel is used in more than 50% of total generation by utilities in the geographical area within a country or the country. To demonstrate this applicability condition data for the last three years should be used. The maximum value of the same fossil fuel generation estimated for three years should be greater than 50%.

4.2.3 Proposed Projects

In December 2007, TATA Power Company Limited (TPCL) submitted a Project Design Document (PDD) using ACM0013 for registering an Ultra Mega Power Plant project in Mundra, India. The new facility will have 4,000 MW installed capacity of five 800 MW supercritical coal-fired units located in a single location. The project will utilise a technology that is more efficient than the standard technology used in India (BAU) and thus should be eligible under ACM0013 to receive CERs as a CDM project.

4.2.4 ACM0013: Baseline Emissions and Additionality.

This section will review the general approach to calculating baseline emissions and constructing an additionality argument under ACM0013.

As mentioned earlier, additionality is a core requirement for a project to be eligible as a CDM project. In order to show additionality two steps have to be followed. A baseline in the country, where the project is going to take place has to be set up against which the proposed project is compared. The proposed project needs to be additional (better) than what would happen in a business-as-usual scenario in the country.

(i) The Baseline Emissions Approach under ACM0013

In order to identify a baseline scenario, a project developer has to follow two steps.

Step 1

A plausible baseline scenario needs to be identified, including all possible realistic and credible alternatives that provide outputs or services comparable with the proposed CDM project activity (including the proposed project activity without CDM benefits), i.e. all types of power plants that could be constructed as an alternative to the project activity.

These alternatives should include:

1. The project activity not implemented as a CDM project;
2. The construction of one or several other power plants instead of the proposed project activity, including:
 - a) Power generation using the same fossil fuel type as in the project activity, but technologies other than that used in the project activity;

- b) Power generation using fossil fuel types other than that used in the project activity;
 - c) Other power generation technologies, such as renewable power generation;
3. Import of electricity from connected grids, including the possibility of new interconnections.

Furthermore, it is possible to distinguish two options to compare the emission reductions of the proposed project to alternatives:

• **Option 1:**

Emissions are based on the average emissions of similar project activities which are being planned by the India' official regulatory authority, in this case the CEA's expansion plan.

• **Option 2:**

Emissions are based on the average emissions of similar project activities undertaken in the previous five years, in similar social, economic, environmental and technological circumstances, and whose performance is among the top 20 per cent of their category.

Plausible Baseline Emissions scenarios are then calculated using the most conservative of either Option 1 or Option 2. Once Step 1 is completed, project participants will then have to identify the economically most attractive baseline scenario.

Step 2

Identifying the economically most attractive baseline scenario alternative includes the economically most attractive baseline scenario alternative identified using an investment analysis. The levelised cost of electricity production, in US\$/kWh, should be used as financial indicator for the investment analysis, comparing the different options identified in Step 1. All relevant costs, revenues, and as appropriate, non-market cost and benefits in the case of public investors should be included.

The investment analysis has to be presented in a transparent manner and all relevant assumptions have to be provided in the CDM-PDD, so that a reader can reproduce the analysis and obtain the same results.

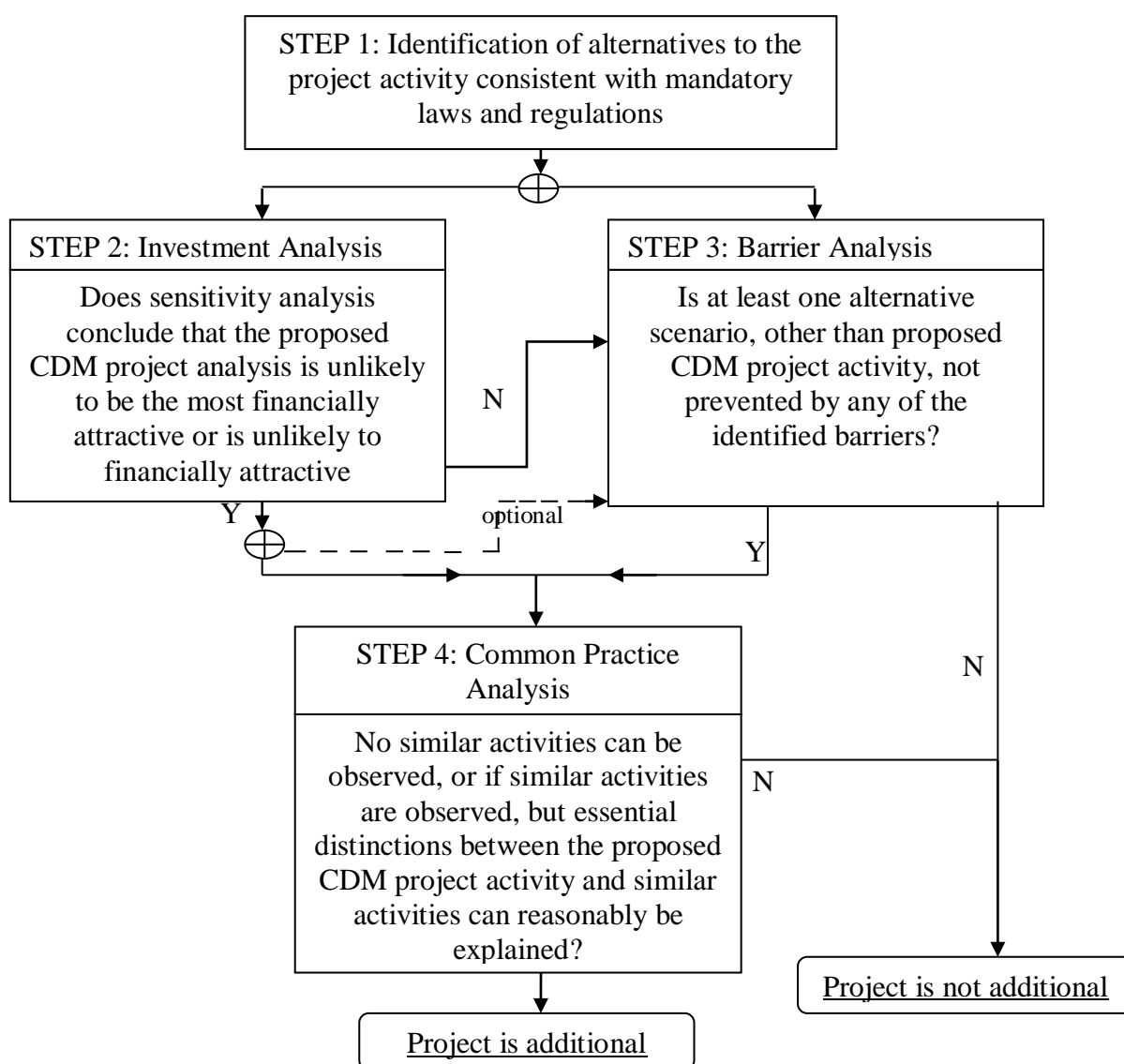
Critical techno-economic parameters and assumptions (such as capital costs, fuel price projections, and lifetimes, the load factor of the power plant and discount rate or cost of capital) have to be clearly presented. Assumptions need to be justified and/or cited in a manner that can be validated by an independent validator.

In calculating financial indicators, the risks of the alternatives can be included through the cash flow pattern, subject to project specific expectations and assumptions (e.g. insurance premiums can be used in the calculation to reflect specific risk equivalents). Where assumptions, input data, and data sources for the investment analysis differ across the project activity and its alternatives, differences should be well substantiated.

(ii) Additionality Approach under ACM0013

In order to demonstrate additionality, a “Tool for the demonstration and assessment of additionality” was developed and needs to be followed. The steps to undertake are shown in Figure 4-1.

Figure 4-1: General additionality approach



(iii) An Additionality Argument for Advanced Supercritical Coal Plants

The following additionality argument for advanced supercritical is based on the TATA PDD, but has been updated to reflect extra and incremental risks associated with ultra supercritical power plants.

The proposed project activities involve power generation using advanced supercritical technology. No advanced supercritical power plant is yet operational in India. This demonstrates the real uniqueness of the project. The technology has achieved very limited penetration in India due to investment, technology and other barriers as elaborated below.

The project proponent is facing certain barriers which may hinder the project proponent in successful implementation of the project activity. Additionality can be shown using the barriers summarized below.

Investment barrier

Advanced supercritical coal plants carry the risk of financing and implementing a technology for the first time in India. As the technology is new to the Indian power generation sector, there are risks that the technology will not be very successful due to unforeseen reasons. The project proponent is also subject to a risk of not receiving the payment on time (payment default risk) on account of poor health of the State Electricity Boards who will be the major consumers of electricity generated from the project activity.

Some of the proposed power projects will be operated on imported coal, which implies a risk of volatility in coal prices in the international market. If coal prices are high the project may rank low resulting in uncertainty over dispatch recovery of capacity charges, incentive income etc.

Technological barriers

Technological barriers can include negative flow characteristic and slagging, as well as thermal fatigue cracking, which are caused by the combined action of elevated metal temperature and thermal cycling. Fire side corrosion is also a major contributor to thermal cracking.

Imported coals from Indonesia, Australia and African countries, which some of the projects might use, have a higher mineral content with significantly more clay minerals present. These clay minerals will tend to melt at relatively low temperatures, indicating a higher potential for problematic slagging. In an advanced supercritical boiler, spiral tube configuration is used in the furnace to produce a high fluid mass flux in the tubes. The design and inclination of the tubes increases the propensity of slag and clinker to form on the walls compared to vertical tubes used in sub-critical power plants.

India does not have a synchronous, state-of-the-art, nation-wide transmission grid, which result in huge transmission losses and transmission constraints even within limited regions. In that case the power plant has to run at lower capacity utilization. This can adversely impact the profitability of the proposed project activity and also reduce the lifetime of the power plant equipments.

Significant risks exist as there is lack of local knowledge of the new technology and lack of skilled personnel to understand the technology and operate the equipments.

There is also the need to procure critical equipments from developed countries which adds to the possibility of increase in the overall project cost on account of foreign exchange dynamics and uncertainties inherent to the economies of the seller countries, and schedule delivery risks.

The barrier analysis is used to show that the project is additional and would not be undertaken in the country or a specific region, due to obstacles that cannot be overcome without the extra revenue that can be gained through CERs.

4.3 Post-2012 CDM Institutional Issues

The first commitment period of the Kyoto Protocol runs until the end of 2012. Parties to the Kyoto Protocol have been negotiating the second commitment period since December 2005 and in December 2005 all parties under the UNFCCC agreed to complete negotiations on a comprehensive framework (including the Kyoto Protocol commitment) by December 2009.

The latest UNFCCC Conference of Parties/Meeting of Parties (UNFCCC) showed uncertainties over a post 2012 agreement and disagreement on the future of the Kyoto Protocol and binding emission targets. The main issues during the Bali conference in December 2007 were the following:

- The EU-27 committed to a reduction of emissions by 20% in 2020 without a further international agreement.
- A number of non-EU countries resisted binding targets. In particular, the USA stated that it is unwilling to enter into an agreement as long as India and China do not undertake to reduce greenhouse gas emissions.
- All countries agreed on the seriousness of climate change and that something need to be undertaken, but the Conference did not result in any commitment and future negotiations will entail compromises if an agreement is to be reached.
- India could be affected by a post-2012 agreement in a number of ways, but the shape of this agreement is not known yet. In the next two years, it will become clearer how an agreement post-2012 will impact on India and its post-2012

CDM market, which also depends on India's negotiation position in the coming years.

Projects registered as CDM projects pre 2012 should not be affected, and as indicated in the sections below even though the political path is uncertain there is significant interest in the carbon community for post 2012 CERs.

4.4 CER Pricing Risks

4.4.1 The Basis of Value

The market for carbon encompasses a number of different but interconnected mechanisms, allowances, obligations and certificates. Carbon transactions can generally be grouped into two main categories:

- **Allowance-based transactions**, in which the buyer purchases emission allowances created and allocated by regulators under cap-and-trade regimes, such as Assigned Amount Units (AAUs) under the Kyoto Protocol, or European Union Allowances (EUAs) under the European Union Emissions Trading Scheme (EU ETS).
- **Project-based transactions**, in which the buyer purchases emission credits from a project that can verifiably demonstrate GHG emission reductions compared with what would have happened otherwise. The most notable examples of such activities are under the CDM and the JI mechanisms of the Kyoto Protocol, generating CERs and ERUs respectively and credits generated for use in the voluntary markets.

In 2006 the global carbon market was valued at US\$30 billion of which US\$25 billion represented the sale and re-sale of EUAs on the EU ETS. This dominance of global carbon transactions by the EU ETS means that it is the value of EUAs that is generally acknowledged to set the price of other carbon assets. In addition CERs can, up to a limit, be used within the EU ETS market in place of an EUA for compliance and thus the value of issued CERs (traded in what is known as the 'secondary' CER market) is closely linked to the value of an EUA. Delays to the launch of the International Transaction Log (ITL) which links together the national registries and the CDM registry means that CERs cannot yet be used in place of EUAs and thus trade at a slight discount to the EUA price.

Deals for CERs from a given CDM project are often negotiated prior to the completion of a project and issuance of any credits; this is known as the 'primary' CER market. The prices agreed for these yet to be issued CERs are lower than those seen in the secondary market since they must take into account the risk that the CDM project may not perform as expected.

The price-setting role of the EU ETS on global carbon markets is firmly anticipated to remain key until the end of the current compliance period of the Kyoto protocol – on 31 December 2012. After this period pricing becomes much more uncertain since the

global political commitments that drive the market will expire and negotiations as to what systems, mechanisms and commitments should exist post-2012 have yet to be concluded.

CHAPTER 5 OTHER RISKS - INVESTIGATION

5.1 Infrastructure - Grid stability:

Stakeholders of UMPP would be having a question that whether the Indian grid is capable of sustaining stability should a large unit go offline unexpectedly. Since ultra supercritical plants are likely to employ larger unit sizes (800-1,000 MW) the consideration of grid stability becomes more important when deploying ultra supercritical technologies.

5.2 Transport Infrastructure

An NTPC supercritical project was recently delayed due to the collapse of a bridge as heavy plant was crossing it on route to the site location. With this incident fresh in stakeholder's minds the ability of Indian transport infrastructure (roads, rail lines, bridges etc) to support the movement of heavy plant to inland pithead sites was a risk raised by numerous stakeholders.

This infrastructure risk is especially pertinent to high supercritical and ultra supercritical technologies which use bigger unit sizes with larger and heavier associated parts. Delays due to transport issues and /or associated costs of upgrading infrastructure could be considerable.

To mitigate this risk transportation issues should be considered when UMPP sites are selected and, where necessary work on upgrading transport infrastructure should be undertaken at an early stage to prevent project implementation delays.

Since the extent of this risk and associated costs will vary considerably on a site to site basis. But it is acknowledged that in some cases depending on site location infrastructure issues could ultimately limit the use of larger unit sizes and so more efficient technologies.

This issue is not relevant to coastal sites where large parts can be shipped to site.

5.3 Site location – distance from centres of electricity demand:

Electricity demand is generally not close to coastal sites, but inland.

5.4 Site location – seismic activity:

Some Proposed UMPP locations sit in seismically active areas, which increases both construction costs and the risks of forced outages.

5.5 Other Fuel Related Risks

In addition to the fuel related impacts on technology costs risks already mentioned stakeholders raised a number of additional fuel related risks.

5.5.1 Fuel security of supply – International:

Since large quantities of international coal will be required for each UMPP plant stakeholders regarded ensuring a secure supply of fuel a risk – especially given that potential sources of supply are located in politically unstable countries. If coal supply is interrupted then this could affect plant performance and variable and fixed O&M costs if coal of a different specification, for which the plant was not designed, has to be used.

5.5.2 Fuel price risk – international:

Since large amounts of international coal are required for the coastal UMPPs fluctuations in the cost of this input could negatively impact project economics.

Both these fuel risks apply to coastal UMPP projects regardless of the technology employed but they are mitigated by the use more efficient plant since fuel costs are proportionally less.

CHAPTER 6 QUESTIONNAIRE

(DUBEYJI insert general risk questionnaire here)

Risk , Risk assessment and control of the risk have become fundamental to the success of a major project. The variation in the use of such risk analysis are considerable and are dependent on numerous factors such as industry sector, the size of project , and stages of project life cycle. These variations and factors have been investigated via a questionnaire and is an element of an on-going research into the application of risk management in major projects .

Following are the questionnaire based on the general risk management for UMPPs:-

1) What are the key risks and concerns that being faced when considering investing in UMPPs? Have these risks and concerns reduced over a period of time?

Questionnaire – Post-2012 Carbon Market

The Government of India is planning to develop at least nine coal-fired Ultra Mega Power Projects (UMPPs), each of 4,000 MW capacity, through private competitive bidding. Three projects have already been awarded and further projects are at various stages of development. To date, each of the published UMPP Request for Proposals (RFP) has stipulated minimum steam cycle parameters that imply that project developers will utilize supercritical rather than the subcritical technology currently prevalent in India. There is potential for 1.5-3.0 million CERs per year per plant if the UMPPs use advanced super critical coal technology.

Decisions on which technology to employ are currently being made by the potential developers of the UMPPs but the plants will not be operating until post-2012.

The aim of this short survey is to investigate current views from carbon funds and credit off-takers regarding post-2012 transactions.

We would very much appreciate it if you could take a few minutes to fill in the questions below. Please note that your answers will be kept anonymous and will be used to form a view on post-2012 market confidence and the mechanisms that may need to be put in place to increase such confidence.

1. Do you have a view on the long term post 2012 value of carbon and in which range do you expect the post-2012 CER price to be?
2. Are you interested in post 2012 transactions as an off-taker and/or also investor? If not,explain why?
3. What price range, volume and contract conditions would you expect to see for you to enter into a post 2012 deal?

4. Would you consider buying CERs from UMPP projects and at what price?
5. Would you consider investing/financing in UMPP projects? Please explain.
6. Do you think that the introduction of large volumes of CERs/year from supercritical coal plants such as the UMPP projects would depress prices significantly?

Thank you very much for your cooperation.

CHAPTER 7 CONCLUSION

7.1 Summary of Key Findings

Risks Identification through literature review

We have identified 23 key risks associated with deploying advanced coal technologies in the Indian market. These risks can be categorized into the following groups:

- **Plant performance risks**
 1. Utilizing Indian coals in advanced coal plants
 2. Impact of Indian ambient conditions
 3. Quality of and licensing issues surrounding Chinese sourced plant
- **Technology cost risks**
 4. Advanced coal Capex and O&M costs
 5. Indian fuel quality impact on costs
 6. Limited number of suppliers compounded by high international demand
 7. Construction time
 8. Fuel quality – international – sulphur
 9. Fuel quality – Indian – high ash content
- **Local capability/experience risks**
 10. Manufacturing- Plant and Spares
 11. Trained Staff- Operation and Maintenance
 12. Experience of Advanced Technologies in India

- **CDM risks**
 - 13. Baseline Applicability
 - 14. Post 2012 rule changes
 - 15. Post 2012 CER pricing risks
 - 16. Transaction costs
 - 17. Price Crash due to UMPP credits flooding the market
- **Other fuel related risks.**
 - 18. Fuel Security of Supply – international
 - 19. Fuel Price Risk – international
- **Other Risks**
 - 20. Infrastructure grid stability
 - 21. Infrastructure – transport
 - 22. Site Location – Distance from centres of electricity demand
 - 23. Site Location – Seismic activity

Of the risks identified, those most significant to the decision making process of UMPP bidders were identified as:

- plant performance under Indian conditions
- economic viability of advanced technologies
- post-2012 CER value.

Further study can be carried out on Efficiency modeling and Techno-economic modeling to reach conclusion on economic viability of advanced super critical plants in India. Mitigation Strategy can be developed for above risks by interviewing stakeholders in our further study.

