Climate Investment Funds

CTF/TFC.2/4
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Washington, D.C.
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CLEAN TECHNOLOGY FUND
CRITERIA FOR FINANCING LOW-CARBON OPPORTUNITIES IN COAL AND GAS POWER INVESTMENTS

Introduction

1. The CTF Trust Fund Committee, at its meeting in November 2008 "reviewed the criteria proposed in document CTF/TFC.1/3 and approved the paper, with the exception of paragraph 7, subject to the revisions proposed by the Committee". The Secretariat was also requested to prepare a technical note regarding the criteria to be applied in CTF financing for carbon capture and storage-ready coal power plants, fuel switching from coal to gas, and rehabilitation of coal-fired power plants.

2. The CTF design document agreed in Potsdam in May 2008, which provides the basis for the World Bank Board's consideration and approval of the establishment of the Climate Investment Funds, states that financing from the CTF could cover, among other low carbon technologies such as renewable energy, the following transformational investments:

> "Switch to highly efficient gas plants resulting in reduced carbon intensity of power generation"; and

> "Achieve significant greenhouse gas reductions by adopting best available coal technologies with substantial improvements in energy efficiency and readiness for implementation of carbon capture and storage."

3. The design document further states that the CTF "would not support technologies that are still in the research stage, but should be focused on deployment which may include demonstration of new low-carbon technologies".

4. The purpose of this note is to provide more detailed criteria for CTF co-financing of low carbon opportunities in coal and gas power investments. The document draws on analyses and conclusions contained in the IPCC Fourth Assessment Report, the International Energy Agency's Energy Technology Perspectives 2008, and the Massachusetts Institute of Technology's study on "The Future of Coal" (MIT, 2007).

Analyses of mitigation technology options

Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report

5. The IPCC Fourth Assessment Report states that "there is no single economic technical solution to reduce GHG emissions from the energy sector.

> "... currently, fossil fuels provide almost 80% of world energy supply; a transition away from their traditional use to zero- and low-carbon emitting modern energy systems (including carbon dioxide capture and storage (CCS) (IPCC, 2005), as well as improved energy efficiency, would be part solutions to GHG-emission reduction. It is yet to be determined which technologies will facilitate this transition and which policies will provide appropriate impetus, although security

of energy supply, aligned with GHG-reduction goals, are co-policy drivers for many governments wishing to ensure that future generations will be able to provide for their own well-being without their need for energy services being compromised.

…. A mix of options to lower the energy per unit of GDP and carbon intensity of energy systems (as well as lowering the energy intensity of end uses) will be needed to achieve a truly sustainable energy future."

6. Similarly, the IPCC Third Assessment Report notes that "energy supply and end-use-efficiency technology options … showed special promise for reducing CO_2 emissions from the industrial and energy sectors. Opportunities included more efficient electrical power generation from fossil fuels, greater use of renewable energy technologies and nuclear power, utilization of transport biofuels, biological carbon sequestration and CCS." The IPCC concluded that low-carbon technologies and systems, such as optimization of generation plant-conversion efficiencies, fossil-fuel switching, renewable energy and CCS, "are unlikely to be widely deployed unless they become cheaper than traditional generation or if policies to support their update (such as carbon pricing or government subsidies and incentives) are adopted."

7. The IPCC assessment is based on the fact that coal is the world's most abundant fossil fuel and continues to be a vital resource for many countries. In 2005, coal accounted for around 25% of the total world energy consumption and approximately 9.2 $GtCO_2$/yr into the atmosphere. "The demand for coal is expected to more than double by 2030 and IEA has estimated that more than 4500 GW of new power plants (half each in developing and developed countries) will be required in this period …. The implementation of modern high-efficiency and clean utilization coal technologies is key to the development of economies if effects on society and environment are to be minimized."

8. With respect to gas, the IPCC Fourth Assessment Report states that natural gas production has been increasing globally, from 1994-2004; it showed an annual growth rate of 2.3%. Natural gas presently accounts for 21% of global consumption of modern energy and 5.5 $GtCO_2$ annually to the atmosphere. "Natural gas-fired power generation has grown rapidly since the 1980s because it is relatively superior to other fossil-fuel technologies in terms of investment costs, fuel efficiency, operating flexibility, rapid deployment and environmental benefits, especially when fuel costs were relatively low. Combined cycle, gas turbine (CCGT) plants produce less CO_2 per unit energy output than coal or oil technologies because of the higher hydrogen-carbon ratio of methane and the relatively high thermal efficiency of the technology …. Despite rising prices, natural gas is forecast to continue to be the fastest growing fossil fuel energy source worldwide IEA 2006), maintaining average growth of 2.0% annually …."

9. The Fourth Assessment Report conducted an analysis of electricity-supply mitigation potential by 2030, which concluded that between 3.95 and 7.22 $GtCO_2$-eq could be avoided by fuel switching, CCS and displacing some fossil fuel generation with

low carbon options of wind, solar, geothermal, hydro, nuclear and biomass. In the higher mitigation scenario (which is a reduction of around 45% of GHG emissions below the baseline scenario):

a) Efficient fossil-fuel generation without CCS would account for 37% of total generation
b) New renewable energy generation would increase to 34% of total generation
c) Nuclear power would account for 17%
d) Coal- and gas-fired power plants with CCS 12%.

International Energy Agency (IEA) Energy Technology Perspectives 2008

10. The IEA Energy Technology Perspectives (ETP) 2008 concluded that the global energy economy will need to be transformed over the coming decades if global CO_2 emissions are to be reduced by 50% from current levels by 2050, so that global warming can be confined to between 2 degrees C and 2.4 degrees C (IPCC, Fourth Assessment Report). According to IEA, energy efficiency improvements in buildings, appliances, transport, industry, and power generation represent the largest and least costly savings. Next in the hierarchy of importance come measures to substantially decarbonize power generation. This can be achieved through a massive deployment of renewables, nuclear power, and carbon capture and storage (CCS). The key message of the IEA report is that "emissions can only be cut significantly if all CO_2-free options play a role".

11. The IEA report projects that end-use energy efficiency will account for 36% to 44% of emissions reductions in ACT (returning global emissions to today's level by 2050) and BLUE (halving emissions by 2050) map scenarios, compared to the baseline. . In the BLUE scenario, renewables represent 21%, CCS represents 19% of reductions, power generation efficiency and fuel switching 7%, and nuclear 6%.

12. In the BLUE map scenario, the share of coal in power generation declines from 52% in the baseline scenario to 13%. The share of gas declines from 21% to 17%, reflecting the fact that CCS – applied to virtually all coal-fired power plants in this scenario – is significantly more expensive per ton of CO_2 saved for gas than coal. About 76% of gas-fired power is generated from plants equipped with CCS. In capacity terms, however, the share of plants with CCS is much lower, as gas peaking plants play an important role in the scenario. They act as backup for variable renewable energy, with a low number of operating hours.

Massachusetts Institute of Technology (MIT): The Future of Coal

13. In 2007, MIT conducted a study of "the role of coal as an energy source in a world where constraints on carbon emissions are adopted to mitigate global warming". It concluded that:

a) The challenge for governments and industry is to find a path that mitigates carbon emissions yet continues to utilize coal to meet urgent energy needs, especially in developing economies.
b) Coal use will increase under any foreseeable scenario because it is cheap and abundant.
c) Carbon capture and storage (CCS) is the critical enabling technology that would reduce CO_2 emissions significantly while also allowing coal to meet the world's pressing energy needs.

Criteria for Financing Highly Efficient and CCS-Ready Coal-Fired Power Plants

14. The CTF will finance new coal-fired power plants that achieve significant greenhouse gas reductions by adopting best available coal technologies with substantial improvements in energy efficiency and readiness for implementation of carbon capture and storage. In order to ensure that the CTF supports low carbon energy supply options, and to provide operational guidance to recipient countries and MDB staff, it is necessary to have a practical working definition of "high efficiency" and "CCS-ready" for coal-fired power plants.

15. According to the IEA's ETP 2008 report, new subcritical steam power plants using hard coal with conventional environmental controls operate at about 40.2% efficiency, with emissions factor of 0.83 t CO_2/MWh (net).[1] IEA states that supercritical steam-cycle plants operate with net thermal efficiencies in the range of 42-44%. The emission factor for the typical supercritical plant (250 bar/560°C/560°C) is 0.80 t CO_2/MWh (net); it "has become the system of choice for new commercial coal-fired plants in many countries".[2] [3] In most developing countries, CO_2 intensity of coal-fired power plants is higher.

16. The CTF's objective is to finance transformational action.[4] Therefore, its investments should reflect a step-change in the carbon intensity of coal-fired power plants in order to qualify as a low carbon technology. For purposes of eligibility for CTF co-financing of new coal-fired power plants, the following approach is proposed:

a) Carbon intensity of the power plant must be lower than 0.795 t CO_2/MWh (net) based on a reference plant with defined site ambient conditions and coal type, as outlined in Annex 1.[5]

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[1] Using different operating assumptions, the MIT study projects an efficiency level of 34.3% for subcritical plants and CO_2 emissions of 0.93 t CO_2/MWh.
[2] Using different operating assumptions, the MIT study projects an efficiency level of 37-40% for supercritical plants and emissions of 0.83 t CO_2/MWh.
[3] The MIT study notes that "there is no clear dividing line between supercritical and ultra-supercritical".
[4] At its November 2008 meeting, the CTF Trust Fund Committee "reaffirmed that, in any case, CTF funds will not be used to support sub- or super-critical coal power plants".
[5] "Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Final Report", U.S. Department of Energy/National Energy Technology Laboratory, August 2007.

b) For each specific proposal for CTF co-financing, the 0.795 t CO_2/MWh (net) threshold will be adjusted to reflect the fact that efficiency and emissions are affected by the following country and site-specific factors:

    i. **Ambient conditions -** Temperature and pressure of air and cooling water are the primary determinants; air humidity is a second order determinant, too. Elevation also has an impact, affecting temperature, pressure and air density. Higher temperature and pressure reduces plant efficiency, while lower temperature and pressure increase efficiency. The higher the elevation, the lower the efficiency.
    ii. **Choice of the cooling type** –
        a. Direct Cooling: Direct cooling system is most efficient due to heat exchanging characteristics with compact condensers. The most efficient of the three options, but water needs to be available.
        b. Tower cooling is used when the direct cooling is not possible, requiring plenty of make up water. Efficiency in between air-cooled and direct cooling.
        c. Air-cooled due to unavailability of water supply for the cooling system. The least efficient of the three options, but maybe be necessary when there is no water available.
    iii. **Coal quality**; Coal quality has many characteristics which impact the heat rate and CO2 emissions –
        - Heating value the higher the heating value, the higher the efficiency
        - Fixed Carbon
        - Volatile Matter
        - Ash content
        - Carbon content
        - Sulfur content
        - Moisture; higher moisture results in lower efficiency and vice versa. All the other coal quality factors have a second or third order impact on plant efficiency (heat rate).
    iv. **Capacity factor**: Criteria of efficiency/heat rate can be at designed efficiency (at full load or at specified load patters, or at annual average). Design value can be tested at the performance test at taking over of the plant. Annual average will need monitoring after the plant is commissioned.

17. Therefore, an adjustment will be made to the reference plant's emissions factor (0.795 t CO_2/MWh) to reflect these country and site-specific-variables.[6] Then the proposed design's emissions factor will be compared to the "adjusted reference plant". Plant designs, which are at or exceed the maximum carbon intensity of 0.795 t CO_2/MWh adjusted to the site- and country-specific conditions, will not be financed.

Carbon Capture and Storage-Ready

[6] Guidance for MDB staff on adjustments to the reference plant's emissions factor will be prepared.

18. Carbon capture and storage (CCS) involves four main steps:

a) CO_2 capture
b) Transportation to an injection sink
c) Underground geological injection and permanent storage
d) Monitoring and verification

19. CCS technology for power plants is currently at the research and development stage and therefore will not qualify for CTF co-financing. Key technical barriers include the need to improve reliability, reduce costs, demonstrate and validate a high degree of CO_2 retention in various geological formations, and to identify potential leakage routes and long-term isolation procedures. Furthermore, IEA concluded that legal, financial and regulatory frameworks (such as those related to onshore and offshore storage, liability and international movement) "do not currently make CCS from fossil fuel-power power plants economically justifiable". However, the IEA notes that "CO_2 capture and storage for power generation and industry is the most important single new technology for CO_2 savings in both ACT Map and BLUE Map scenarios".

20. According to IEA, four large-scale (over 0.5 Mt injected per year) anthropogenic CO_2 projects were in operation around the world in 2007. The European Union Zero Emissions Technology Platform aims to support the development of 10-12 demonstration plants within Europe by 2020.

21. In parallel with pilot projects to address technological issues, as well as legal and regulatory barriers, IEA's technology roadmap for CCS in fossil fuel power generation recommends "that new power plants should include capture/storage readiness considerations within design by 2015". Drawing on the IEA Greenhouse Gas R&D Programme's study of capture-ready plants, it is proposed that, for CTF co-financing, a new coal-fired plant will be considered CCS-ready if it satisfies the following conditions:

a) Adequate space and access requirements for additional equipment needed to capture CO_2;
b) Identified storage reservoir with enough storage capacity for the lifetime of the plant and feasible transportation options;
c) An economic analysis of CCS options, including economic viability of plant with CCS operation.

22. These conditions match the provisions of draft EU Policy note on Capture Ready[7], which is yet to be finalized as a final EU directive. They are also consistent with the conclusions of the IPPC Fourth Assessment Report:

[7] Accessible at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52008PC0018:EN:NOT or http://ec.europa.eu/environment/climat/ccs/eccp1_en.htm . The proposed directive is the most comprehensive approach available.

> "New power plants built today could be designed and located to be CCS-ready if rapid deployment is desired (Gibbins et al. 2006). All types of power plants can be made CCS-ready, although the costs and technical measures vary between different types of power plants. However, beyond space reservations for the capture, installation and siting of the plant to enable access to storage reservoirs, significant capital pre-investment at build time do not appear to be justified by cost reductions that can be achieved (Bohm, 2006; Sekar, 2005)."

23. There are multiple candidate technologies for electricity production with CCS; however, limited number of coal technology has been demonstrated with CCS. Therefore, the CTF will not pick a technology "winner". As noted in the MIT study, "the reality is that the diversity of coal type … imply different operating conditions for any application and multiple technologies will likely be deployed." Key factors in assessing technology options will be: the pre-CCS emissions factor; efficiency reduction from no-capture to capture; and the cost of applying CCS to the power plant.

Criteria for Financing Rehabilitation and Retrofitting of Inefficient Thermal Power Plants

24. It is proposed that efficiency improvements of existing power plants should qualify for CTF co-financing due to the potential large impact on CO_2 emissions, while recognizing that the preferred option is to switch to new state-of-the-art plants. The IEA notes that "efficiency improvements can significantly reduce CO_2 and other emissions …. Improvements in the average efficiency of coal-fired power plants are already feasible. Two-thirds of all coal-fired plants are over 20 years old. Such plants have an average net efficiency of 29% or lower, and emit at least 3.9 Gt CO_2 per year."

25. For many developing countries, the ability to meet energy demand has been a long-standing problem. In such circumstances, power plants are typically operated well-beyond their normal life expectancy and regular maintenance is less than usual in an effort to reduce black-outs and load shedding. Given the relatively high cost of load shedding to the economy, such an approach is economically prudent. It is not unusual for utilities to invest in life extension to such plants, but there are limited incentives to improve plant efficiency. Plant efficiency upgrades are more expensive than life extension investments and vary considerably depending on the technology and plant condition. A rough estimate of the incremental cost would be $300 - 1000/kW.

26. CTF co-financing could provide positive incentives to power plant operators so that, when plants are taken out of service for life extension investments, they are also upgraded to reduce emissions. Low cost improvements could improve plant efficiency from its operating efficiency by about 2 percentage points (moving, for example, from 28% to 30% efficiency). For CTF eligibility, improvements that would be considered transformational in reducing the carbon intensity of the power sector should require that:

a) Efficiency gains would push the technical limits to 5 percentage points (improvements from, say, 28% to 33%). Improvements beyond 5 percentage points are expected to be beyond what is generally technically viable as these plants are typically old; OR,

b) CO_2 emissions reduction per kWh should be at least 15%.

27. Plants with such investments should be expected to be operational for at least 15 years after the upgrade is complete. Furthermore, the introduction of best practice in plant operation and plan maintenance after retrofitting will be required for CTF co-financing eligibility. Monitoring and verifying efficiency improvements for a certain period of time after retrofitting should be a part of project design.

Criteria for Financing Fuel-Switching to Highly Efficient Gas-Fired Power Plants

28. In many developing countries, new coal-fired plants emit roughly 0.950 t/MWh of CO_2 while older plants emit well over 1 t/MWh in well-run utilities and as high as 1.35 t/MWh for older plants. Gas-fired combined cycle power plants could reduce such emissions considerably as CO_2 emissions would typically be less than half that of a coal-fired plant. But in countries with indigenous coal, this switch is not happening due to under-developed gas markets and policy frameworks, and for price and security of supply reasons. Unlocking the value of gas through effective policy interventions will decrease the cost of importing gas – either by pipe or LNG – and could potentially decrease emissions in a 300 MW plant by more than 1 million tons CO_2 per year.

29. CTF funds could be used to initially buy-down the incremental cost of gas relative to coal. These funds could be used to partially fund either a gas pipeline or an LNG terminal for natural gas, combined cycle plants, either of which would be transformative in decreasing CO_2 emissions as outlined above. The pipeline/LNG terminal could be sized to fulfill multiple power plants, broadening the impact. It is recommended that the net result of the use of gas would be to decrease CO_2 emissions by at least 50% compared to the "Business-As-Usual" case. This would require that high efficiency gas-fired technologies be used.

30. Net carbon intensity of the new gas-fired power plant, or new units within an existing plant, must be lower than 0.398 t CO_2/MWh (net), which is 50% of the threshold for coal-fired power plants. Assumptions regarding natural gas composition for the reference plant are presented in Annex 1. For each specific proposal for CTF co-financing, the 0.398 t CO_2/MWh (net) threshold will be adjusted to reflect the fact that efficiency and emissions are affected by the following country and site-specific factors.

31. Given limited CTF resources, CCS-readiness would be eligible, but not required, for CTF investments in gas-fired power plants, since the lower carbon intensity of gas makes CCS significantly more expensive per ton of CO_2 saved for gas than coal.

Summary of CTF Criteria for Coal and Gas Investments

32. In summary, it is proposed that the CTF Trust Fund Committee approve the following criteria for low carbon opportunities in coal and gas power investments:

a) Net carbon emissions factor of new coal-fired power plants or new units in existing plants should be less than 0.795 t CO_2/MWh, adjusted for site- and country-specific factors.

b) New coal-fired power plants should include CCS readiness considerations in design, such as space, access, storage, transport and costs.

c) Net efficiency improvements in existing coal fired power plants should be at least five percentage points from operating efficiency levels or with net carbon emissions reductions of at least 15%, and will be limited to plants expected to be operational for 15 years after the upgrade.

d) Fuel switching from coal to gas should result in a decrease in CO_2 emissions of at least 50%. Net carbon emissions of new gas-fired power plants or new units in existing plants should be less than 0.398 t CO_2/MWh (net), adjusted for country- and site-specific factors.

Annex 1: Assumptions for Coal- and Gas-Fired Reference Plants [8]

Exhibit 2-1 Site Ambient Conditions

Elevation, m (ft)	0
Barometric Pressure, MPa (psia)	0.10 (14.696)
Design Ambient Temperature, Dry Bulb, °C (°F)	15 (59)
Design Ambient Temperature, Wet Bulb, °C (°F)	11 (51.5)
Design Ambient Relative Humidity, %	60

Exhibit 2-3 Design Coal

Rank	Bituminous	
Seam	Illinois No. 6 (Herrin)	
Source	Old Ben Mine	
Proximate Analysis (weight %) (Note A)		
	As Received	**Dry**
Moisture	11.12	0.00
Ash	9.70	10.91
Volatile Matter	34.99	39.37
Fixed Carbon	44.19	49.72
Total	100.00	100.00
Sulfur	2.51	2.82
HHV, kJ/kg	27,113	30,506
HHV, Btu/lb	11,666	13,126
LHV, kJ/kg	26,151	29,544
LHV, Btu/lb	11,252	12,712
Ultimate Analysis (weight %)		
	As Received	**Dry**
Moisture	11.12	0.00
Carbon	63.75	71.72
Hydrogen	4.50	5.06
Nitrogen	1.25	1.41
Chlorine	0.29	0.33
Sulfur	2.51	2.82
Ash	9.70	10.91
Oxygen (Note B)	6.88	7.75
Total	100.00	100.00

[8] "Cost and Performance Baseline for Fossil Energy Plants, Volume 1: Bituminous Coal and Natural Gas to Electricity Final Report", U.S. Department of Energy/National Energy Technology Laboratory, August 2007.

Exhibit 2-4 Natural Gas Composition

Component		Volume Percentage	
Methane	CH_4	93.9	
Ethane	C_2H_6	3.2	
Propane	C_3H_8	0.7	
n-Butane	C_4H_{10}	0.4	
Carbon Dioxide	CO_2	1.0	
Nitrogen	N_2	0.8	
	Total	100.0	
	LHV		**HHV**
kJ/kg	47,764		52,970
MJ/scm	35		39
Btu/lb	20,552		22,792
Btu/scf	939		1,040