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CO_2 Emission Reductions due to Renewable Power Generation Projects under a Competitive Electricity Market

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Key Issues Analyzed

- Determining emission reductions due to renewable power generation projects (biomass and solar PV) under a competitive electricity market using a rigorous economic scheduling approach.

- Comparison of estimated levels of GHG emission reduction due to the projects derived from the rigorous economic scheduling and simplified approaches.

Methodology (1)

Steps for calculating the level of CO_2 emission from the power system in a competitive market:

- Determination of optimal (profit maximizing) self-scheduling for each generator (revenue of a CDM project owner includes CER revenue)
- Formulation of the bidding curve for a generator using the information from self-scheduling
- Economic scheduling of generators by the ISO to meet the forecasted demands and
- Calculation of CO_2 emission from individual generators (and the power system as a whole) based on the results of the economic scheduling by the ISO

These steps are repeated for two cases: (i) without the CDM project, and (ii) with the CDM project

Methodology (2): Calculation of CO2 reduction due to CDM/JI plant

- CO_2 mitigation due to the candidate CDM/JI plant is calculated as difference between levels of CO_2 emissions from the power system **with** and **without** the candidate CDM/JI project

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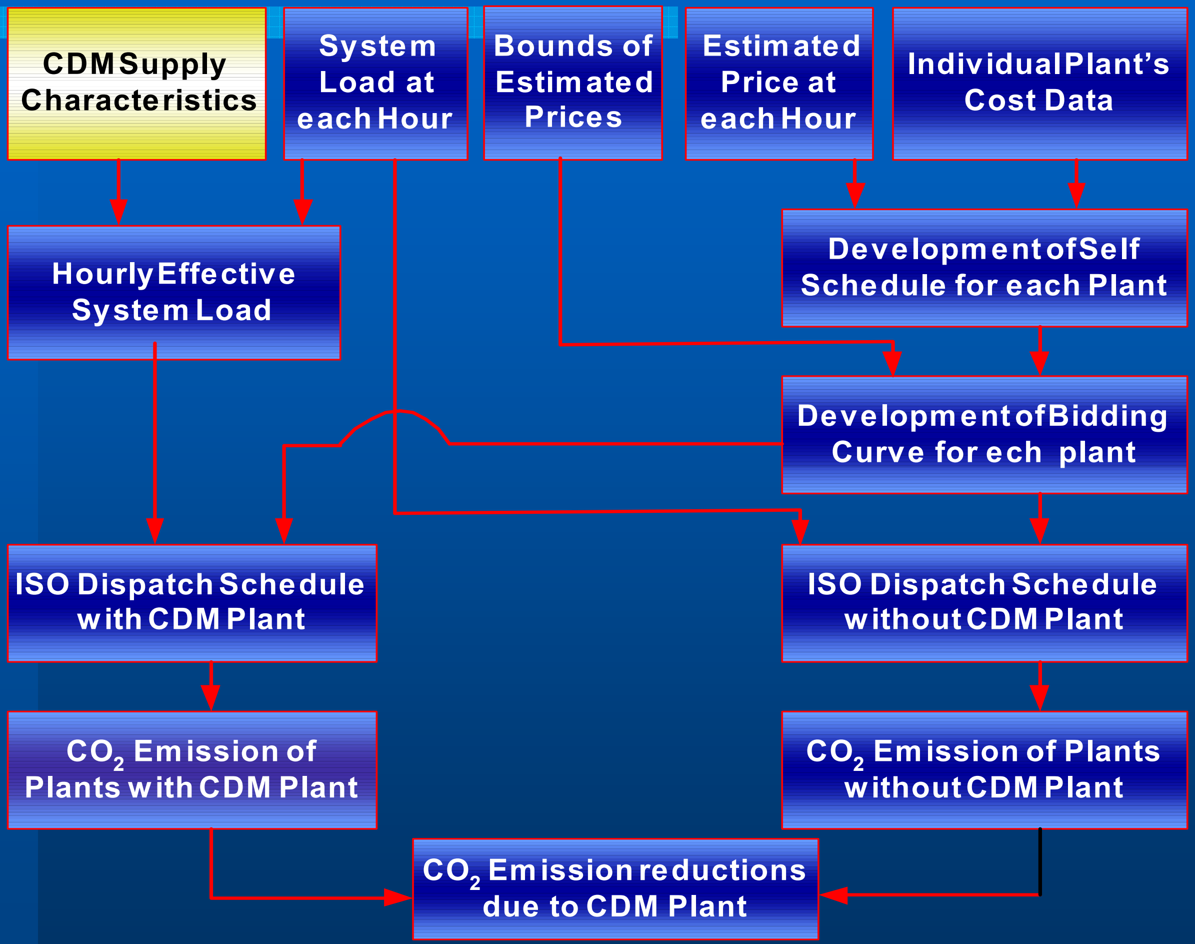
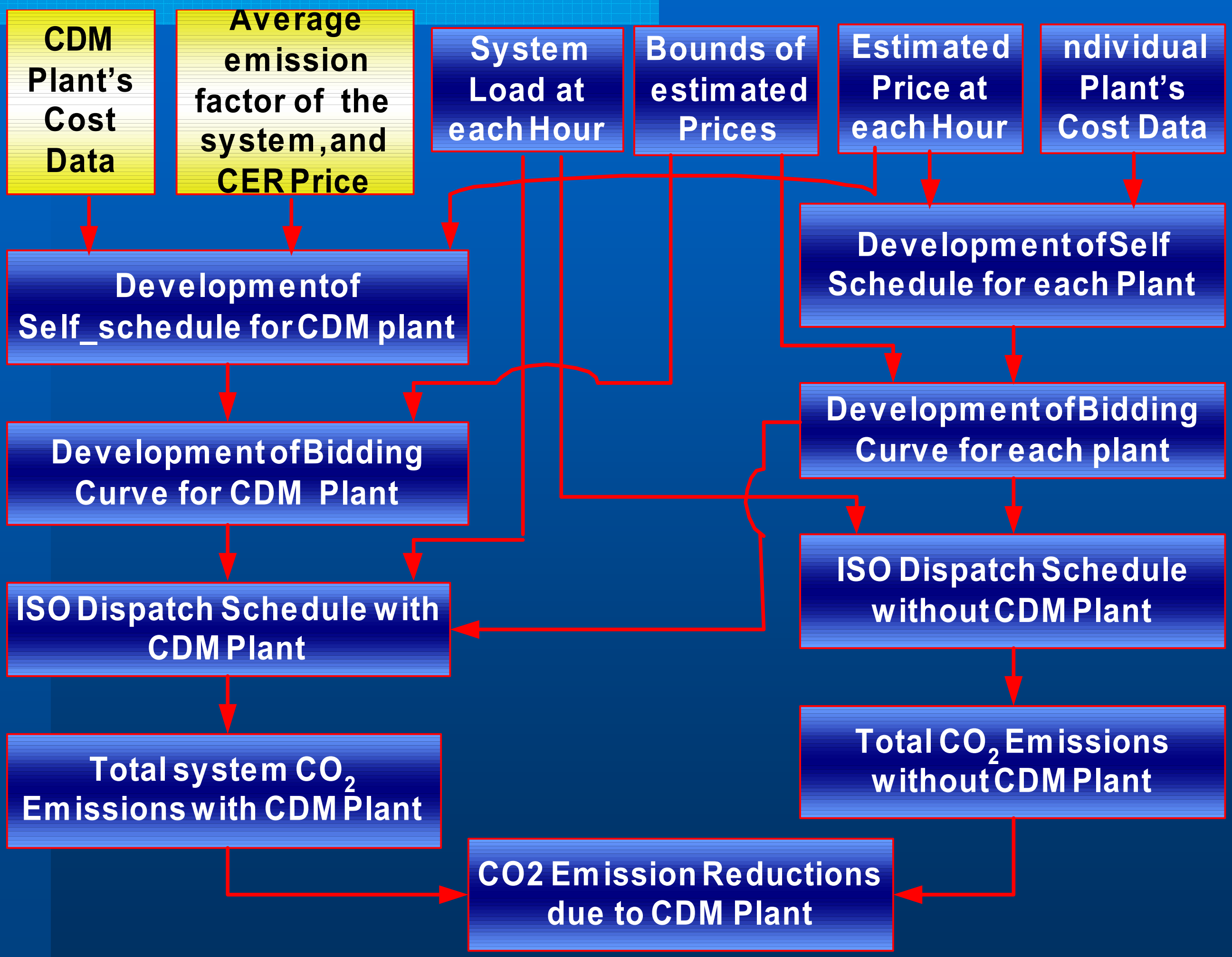
Calculation of Level of CO_2 emissions Due to non-dispatchable renewable plant



Calculation of Level of CO_2 emissions Due to dispatchable renewable plant



Case Study

- A hypothetical power market, which consists of five generators three of which are coal based and two are oil based.
- Two types of CDM/JI plants, i.e., one based on PV (which is non-dispatchable) and other based on biomass (which is dispatchable).
- A perfectly inelastic demand curve was used in ISO dispatch
- We compare the emission reduction derived from the rigorous method with those obtained from the following simplified approaches:
  - System average emission factor based on actual dispatch (Simplified Method A)
  - Generation weighted average approach (Simplified Method B)
  - Straight system average approach (Simplified Method C)

Simplified Methods (1)

Simplified Method A:

System average emission factor based on actual dispatch: Emission baseline here is calculated on the basis of total emission estimated using the data on total fuel consumption and total generation in the system. Note that the emission factors here correspond to the levels of output actually supplied by power plants rather than their rated outputs.

Simplified Method B:

Generation weighted average approach: Here, emission baseline is calculated based on weighted average of emission factor of all power plants in the system, the weights being the generation shares of the plants. The emission factors of individual plants are based on their respective rated output levels.

Simplified Methods (2)

Simplified Method C:

Straight system average approach: In this approach, emission baseline is calculated based on simple average emission factor of all power plants in the system. Here also, the emission factors of individual plants here correspond to the values at the rated output levels of the plants.

Case of Non-dispatchable PV plant

- Analysis was carried out for five different sizes of PV capacities (i.e., 10 MW, 20 MW, 30 MW, 40 MW and 50 MW)
- It is assumed that the ISO will always purchase the expected level of power generation of PV plant (i.e.

  Qt* = expected level of power generation by PV plant)
- Expected level of power generation by PV plant is determined based on expected solar radiation at each hour

Case of dispatchable PV plant

- Analysis was carried out for five different sizes of Biomass capacities (i.e., 20 MW, 40 MW. 60 MW, 80 MW, and 100 MW) and three CER prices (i.e. 2, 3, and 4 US$/t$CO_2$)
- Emission factor of biomass is considered as zero (i.e. E_{CDM} = 0)
- It is assumed that information on baseline CO2 emission factor (E0) (defined as average CO2 emission per unit of electricity generation in the baseline) is available to each participant.

CO_2 emission reductions by generators due to CDM/JI PV power plant of different sizes

CO_2 emission reductions in tonnes

Generator	PV Plant Capacity				
	10 MW	20 MW	30 MW	40 MW	50 MW
Coal1	4.5	12.7	21.0	-2.9	4.9
Coal2	6.1	9.8	13.5	99.9	103.6
Coal3	6.6	13.1	19.6	26.0	52.9
Oil1	2.2	4.5	6.7	38.1	-3.3
Oil2	9.7	19.4	29.0	-7.0	-26.8
Total	29.2	59.7	89.9	114.2	131.5

* The positive figures represent reduction in CO_2 emission while the negative figures represent an increase in the emission

- Total CO_2 emission avoided increases at a decreasing rate with the size of the PV power plant.

Comparison of estimated CO_2 emission reductions (tonnes) due to PV plants derived from economic scheduling and simplified methods

PV Plant capapcity	Electrical energy supplied (MWh)	Approach			
		Economic Scheduling	Simplified Method A	Simplified Method B	Simplified Method C
10 MW	54	29.2	34.1	49.7	51.9
20 MW	108	59.7	68.2	99.3	103.9
30 MW	162	89.9	102.4	149.0	155.8
40 MW	216	114.2	136.5	198.6	207.7
50 MW	270	131.5	170.6	248.3	259.7

- Overestimation when the capacity of PV plant increased from 10 MW to 50 MW:
  - Simplified Method A - 17% to 30%
  - Simplified Method B - 70% to 89%
  - Simplified Method C - 78% to 97%

CO_2 emission reduction due to a biomass power generator, tonnes

Biomass Plant Capacity	CER Price, \$/tonne CO_2		
	2\$	3\$	4\$
20 MW	146.5	148.5	154.6
40 MW	323.5	349.5	354.3
60 MW	470.3	490.4	511.2
80 MW	623.5	674.6	681.4
100 MW	840.3	889.6	890.6

- The emission reduction is observed to increase at an increasing rate with the size of the biomass plant at certain capacity ranges and increase at a decreasing rate at other capacity ranges.

Comparison of estimated CO_2 emission reductions (tonnes) due to biomass plant

Biomass Plant capacity	Electrical energy supplied (MWh)	Type of approach			
		Economic scheduling	Simplified Method A	Simplified Method B	Simplified Method C
20 MW	396.5	146.5	250.6	364.6	381.3
40 MW	793.0	323.5	501.2	729.1	762.7
60 MW	1189.5	470.3	751.8	1093.7	1144.0
80 MW	1586.0	623.5	1002.3	1458.3	1525.4
100 MW	1982.5	840.3	1252.9	1822.8	1906.7

- CO_2 emission reductions in tonnes at CER price of 2$/tonne of CO_2
- All three simplified methods overestimates emission reductions
- Method C is found to cause the largest overestimation, followed by methods B and Method A

Thank You

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