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A MODELLING ASSESSMENT OF THE IMPACT OF CLEAN DEVELOPMENT MECHANISM ON ELECTRICITY GENERATION SYSTEMS :

Case of Shandong Province, China

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Outline

- Motivation and Objectives
- Proposed Approach for Studying CDM Impact
- PLANELEC Model
- CDM Market and It's Implications for Electricity Generation Systems
- Case Study of the Shandong Province, P.R.China
- Findings and Conclusions
- Future Work

Motivation

- Building of new electricity generation capacities is needed to ensure sustainable economic growth
- Necessity to transfer state-of-the-art environmentally sound power generation technologies towards developing countries
- CDM and international carbon trading market offer opportunities for selling CERs, thereby enhancing the competitiveness of low / zero carbon emitting technologies
- CDM may alter the economically efficient load order and capacity deployment
- Possible impact of CDM on the electricity generation systems seems to be positive, but its magnitude is uncertain

Objectives

- Technical-economical assessment of the technology mixes for power generation in medium - to - long term perspective using a least cost electricity system expansion planning model
- Evaluation of the impact of different CERs prices on the total discounted cost of the power generation system and on the shares of prospective CDM technologies in the electricity generation / capacity deployment mix
- Multi-criteria analysis with the aim to determine potential scope and magnitude of CDM projects in a given electricity generation system basing on the example of Shandong province, China

Approach / PLANELEC model

Scenario Assumptions Module

- Projected electricity demand
- Fuel prices
- CERs price range
- Escalation ratios for fuel prices, investment and O&M costs

Technology Selection Module

- Technical-economic characteristics of the existing electricity system
- Technical-economic characteristics of committed and candidate power plants
- Baseline technology choice

Exogenous Constraints Module

- Availability of primary energy
- CO_2 emission cap
- Quality of electricity supply (LOLP, reserve margin)
- Annual energy generation
- Market demand for CERs

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Power Generation System Expansion Planning Module

Simulation and optimisation of possible technologies configurations

- "Baseline" case
- "Clean Coal" (IGCC, AFBC)
- "Wind Power"
- "Natural Gas"
- "Carbon Capture & Sequestration"
- "Integrated" case
- "Nuclear"

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Multi-Criteria Cost / Benefit and Sensitivity Analyses Module

Generation mix

Total System cost

CO_2 emissions

- CERs price
- Fuel prices
- Discount rate

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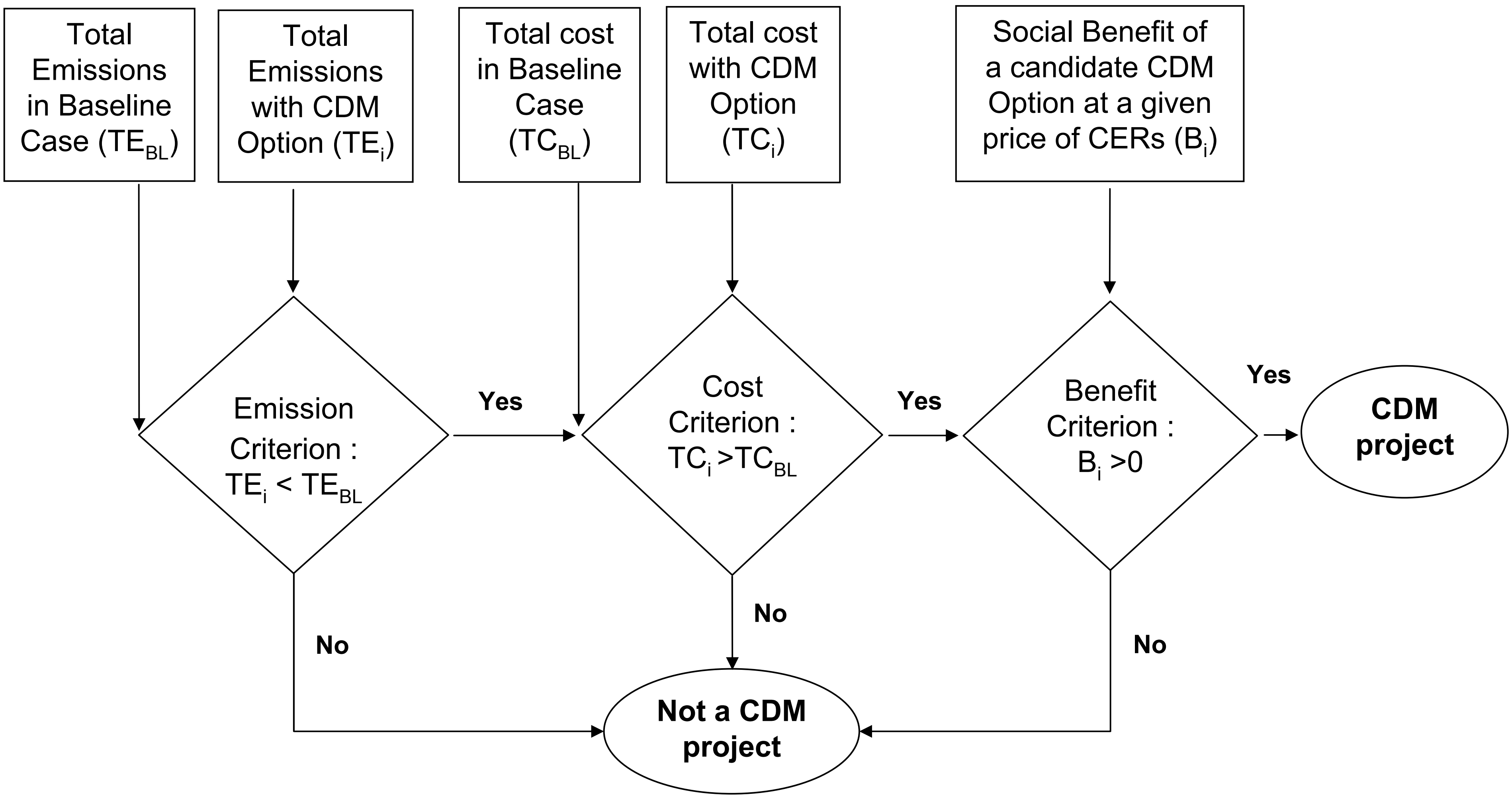
Identification of Optimal Expansion Plan

Clean Development Mechanism



Source: adapted from Shrestha & Shrestha, 2003

Emission Baseline

Marrakech Accords / COP7. Methodology for setting GHG emission baseline can be chosen among the following approaches:

- Existing actual or historical emissions; or
- Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment; or
- 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

OECD/IEA, 2002. Practical Baseline Recommendations for GHG Mitigation Projects in the Electric Power Sector.

- Operating margin methods (*generation-weighted average; dispatch data*)
- Build margin methods (*average of recent capacity additions; or single proxy plant type*)
- Combined margin methods (*Operating* + *Build margin; or basing on electric sector model*)

Global Emission Trading & CDM Market

Model / Author	Traded quantities (million tons CO_2 per year)	Market volume (million US$$_{2000}$ per year)	CDM Market share (%)
ECN	*1239*	*4 956*	*58*
EPPA	*2651*	*21 208*	*77*
G-CUBED	*1815*	*12 705*	*55*
GREEN	*1456*	*10 190*	*60*
HAITES	*2108*	*21 083*	*64*
POLES	*1606*	*12 848*	*68*
SGM	*1665*	*13 317*	*56*
ZHANG	*1071*	*3 212*	*65*

Source: Springer U., 2002

CERs Price and Demand

- **CDM Market Volume:**
  - 256 – 586 million tons of CO_2 per year (CERT model / Chen, 2003)
  - Over 3 billion tons of demand in 2008-2012 (Natsource, 2005)
- **Market price:**
  - CER: 4 – 5 € / tCO_2 (Grütter, 2002; Michaelowa, 2005)
  - EUA: 22.76 € / tCO_2 (Point Carbon, August 2005)
- **IETA survey of 116 carbon market participants** (2003)
  - median carbon price in the end of 2010: 10.5 US$ / tCO_2
  - mean price: 14.3 US$ / tCO_2
  - 75 per cent responses in the range: 6 – 20 US$ / tCO_2

CDM Project Size and Transaction Cost

Size	Reduction (tCO_2 per year)	Transaction cost (€ / tCO_2)
Very large	***> 200 000***	***0.1***
Large	***20 000 – 200 000***	***0.3 – 1***
Small	***2000 – 20 000***	***10***
Mini	***200 – 2000***	***100***
Micro	***< 200***	***1000***

Source: Michaelowa et al., 2003

Shandong Province, P.R.China

Source: http://www.china-sd.com/

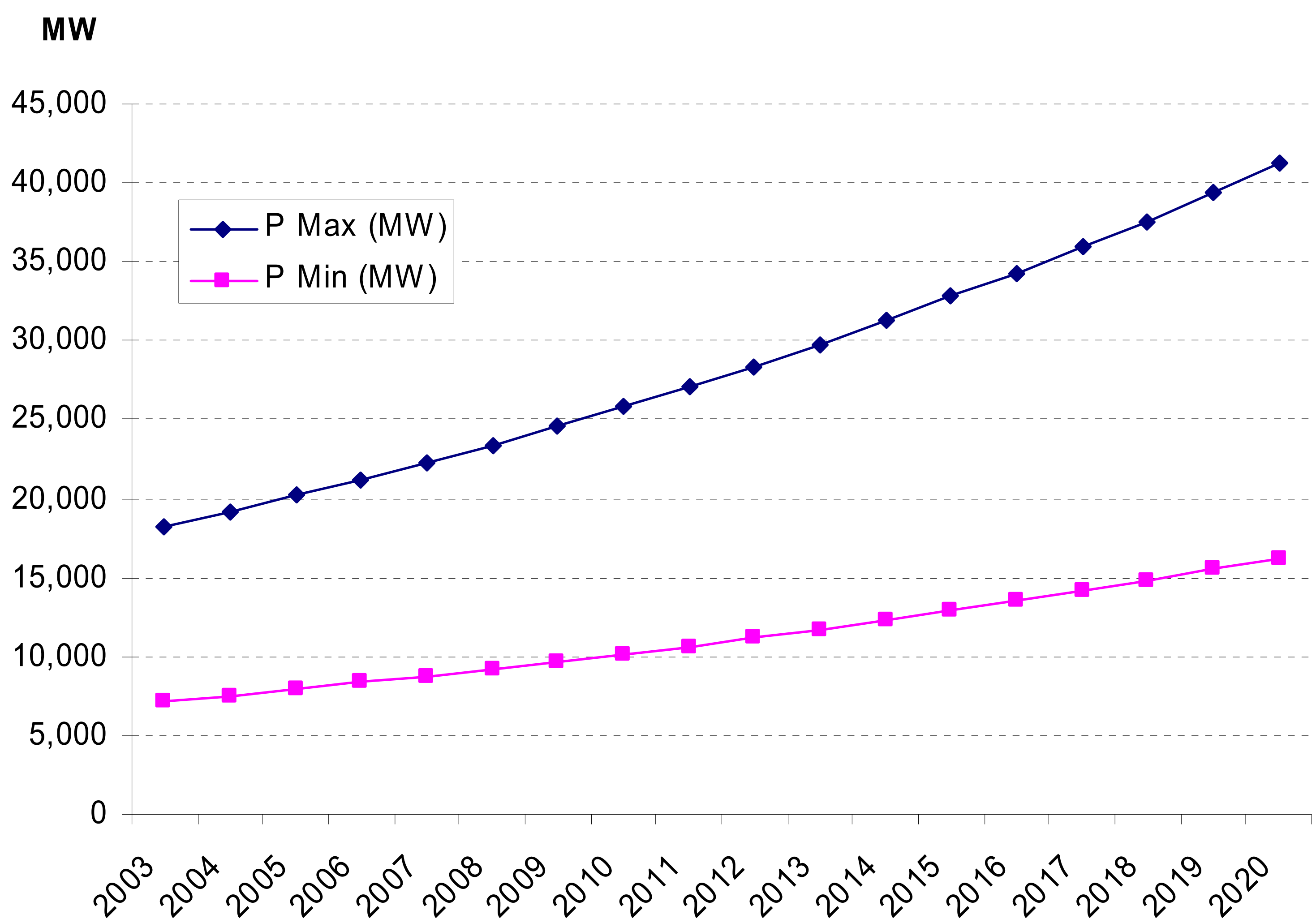
Shandong Province, P.R.China

- Shandong is one of China's most populated and economically productive provinces. It is located in the East of China and constitutes one of several China's free-trade zones along eastern coast.
- Shandong has maintained rapid economic growth over past decade at average annual rate above 10% (SDinternet, 2003). In 1999 Shandong had the third largest GDP in the country with 766.2 billion Yuan or 9.4% of total China's GDP (CSY, 2000).
- Being a model for Chinese economic development, Shandong province typifies also main energy and environmental challenges faced by China as a whole. These include a historically overextended power system (Connors, 2002), reliance on coal and poor air quality.

Shandong Province, P.R.China

- Shandong has relatively abundant primary energy resources. The proven reserves of primary energy in Shandong province include 29 billion ton of coal, 3.42 billion ton of oil and 29.94 billion m^3 of natural gas. There is little hydropower.
- Total power generation capacity in 2000 was 19.7 GW including 16 GW owned by Shandong Electrical Power Corporation (SEPCO) and 3.7 GW owned by the Prefectures and customers.
- All the power plants are fuelled with local coal and coal from the neighbouring Shanxi province. The capacity of units over 300 MW is 45% of the total capacity, while units smaller than 50 MW represent 16% of total capacity.
- In 2002, the total power generation in Shandong was 124’175 GWh (Sepco, 2003).

Electric Load Forecasting, Shandong P.R.C.



Source: Gnansounou & Dong, 2003

Candidate Technologies

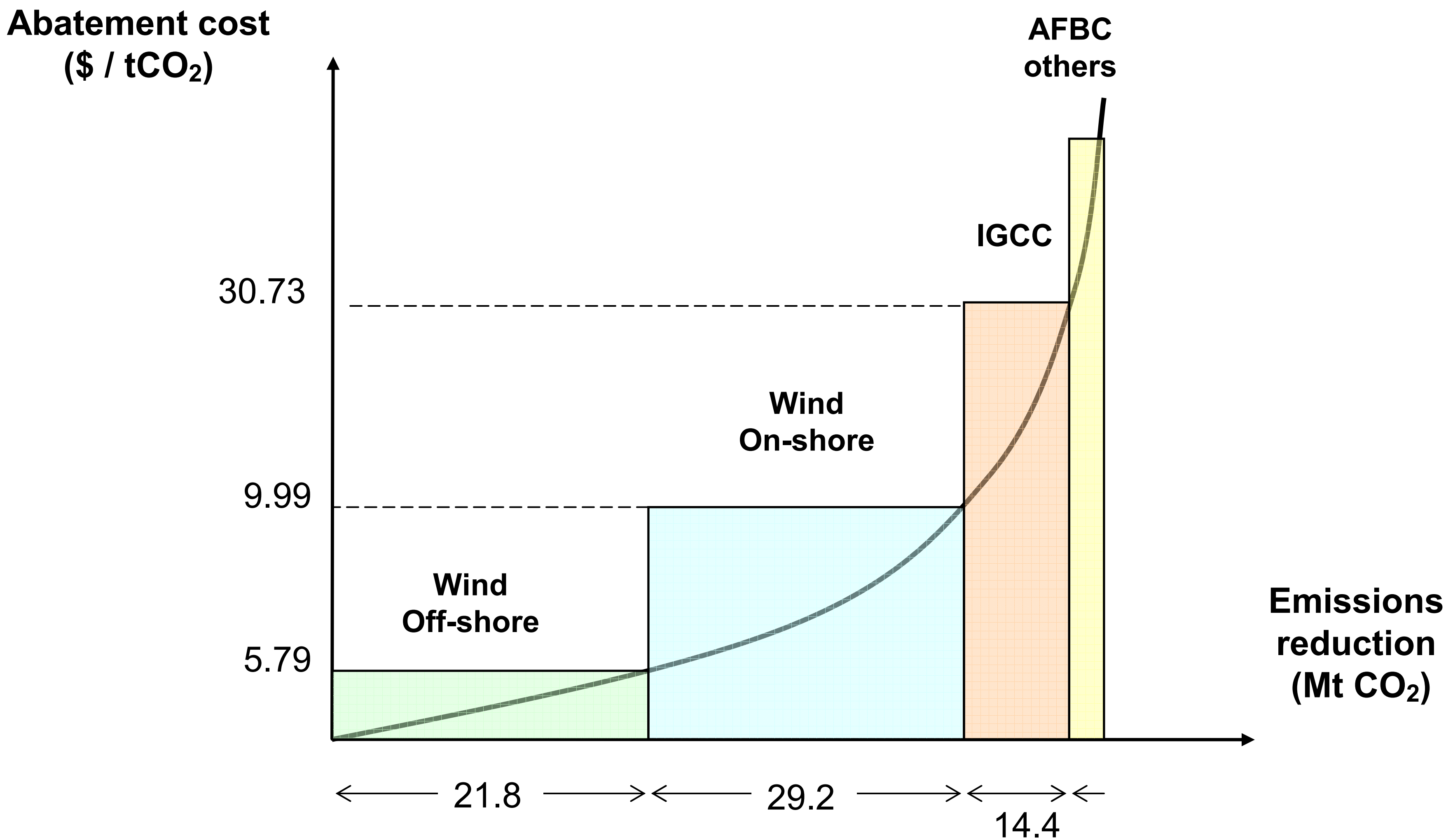
Technology	Unit Capacity	Thermal Efficiency	CO2 intensity	Forced outage	Sched. Mainte-nance	1st year available	O&M fixed	O&M variable	Capital cost
	MW	%	tCO2/MWh	%	days/yr		$/kW* month	$/MWh	$ / kW
CCGT-1	250	58%	0.330	5	21	2005	1	0.5	600
CCGT-2	500	58%	0.330	5	21	2005	0.92	0.5	600
GT	155	38%	0.504	8	10	2005	0.08	3	400
HFOil	50	34%	0.787	5	21	2003	0.44	2.53	500
Nuclear ALWR	1000	33%	-	5	28	2010	3.42	0.5	1400
Pulverized Coal-1	300	35%	0.961	5	49	2003	1.83	2	624
Pulverized Coal-2	600	36%	0.934	5	56	2003	1.67	2	574
AFBC	300	38%	0.885	5	35	2008	2.5	4	900
IGCC	500	45%	0.748	8	35	2010	2.5	2	1200
Wind on-shore	25	-	-	75	-	2003	1.25	5	650
Wind off-shore	50	-	-	65	-	2010	1.67	5	800

Source: based on CETP / Connors, 2002

Results: Electricity generation, CO_2 emissions, and total discounted system cost (2003-2020)

	Total Electricity generated (GWh)	Electricity generated by candidate CDM option (GWh)	Total CO_2 emissions (Million t)	Total discounted cost (Million $)
Baseline case	**3'259'149**	**-**	**2'847**	**35'891**
Wind on-shore	**- // -**	**30'879**	**2'817**	**36'182**
Wind off-shore	**- // -**	**22'670**	**2'825**	**36'017**
IGCC	**- // -**	**76,506**	**2'832**	**36'333**
AFBC	**- // -**	**791**	**2'846**	**36'073**

Results: CO_2 emission reduction (2003-2020) and CO_2 abatement cost



Results: Economic Benefit from CDM (Million $) at given CERs price

Candidate CDM technology	**CERs Price**		
	$10	***$15***	***$20***
Wind on-shore	< 0	< 0	**73**
Wind off-shore	**18**	**90**	**161**
IGCC	< 0	< 0	< 0 (**26** at ***$40***)
AFBC	< 0	< 0	< 0 (**5** at ***$40***)

Conclusions

- CDM offers opportunity to earn additional social-economical benefits while introducing advanced environmentally sound technologies within electricity generation sector
  - ✓ Good potential for deployment of Wind power at current level of carbon prices (5-10 $ / t CO_2)
  - ✓ Limited potential for Clean Coal technologies (require higher CERs price to be economically competitive ≈ 35 - 40 $ / t CO_2)
  - ✓ Carbon Capture & Sequestration technologies can benefit from CDM but still require substantial public support and financing
- Natural gas fired power plants could qualify for CDM if investment additionality criterion is met (*e.g. under conditions of sustained high price of natural gas*)

Future Work

- In-depth analysis of carbon capture & sequestration and other power generation technologies (PFBC, biomass, solar, small hydro…), which potentially may qualify for CDM
- Refining of the methodology for setting CO_2 emission baseline (*taking into account life cycle emissions engendered through primary fuels extraction, preparation and transportation, and differentiating between peak-load / base-load / intermittent installations*)
- Application of advanced "agent-based" modelling approach to study CDM impact in the case of market oriented planning of power generation expansion