The WADE Economic Model: China

A WADE Analysis

December 2004

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WADE

WORLD ALLIANCE FOR DECENTRALIZED ENERGY

About WADE

WADE is a non-profit research and advocacy organisation that was established in June 2002 to accelerate the worldwide deployment of decentralised energy (DE) systems. WADE is now backed by national cogeneration and DE organisations, DE companies and providers, as well as a range of national governments. In total, WADE's direct and indirect membership support includes over 200 corporations around the world.

DE technologies consist of the following forms of power generation systems that *produce electricity at or close to the point of consumption*:

- High efficiency cogeneration / CHP
- On-site renewable energy systems
- Energy recycling systems, including the use of waste gases, waste heat and pressure drops to generate electricity on-site.

WADE classifies such systems as DE regardless of project size, fuel or technology, or whether the system is on-grid or off-grid.

WADE believes that the wider use of DE holds the key to bringing about the cost-effective modernisation and development of the world's electricity systems. With inefficient central power systems holding a 93% share of the world's electricity generation and with the DE share at only 7%, WADE's overall mission is to bring about the doubling of this share to 14% by 2012. A more cost-effective, sustainable and robust electricity system will emerge as the share of DE increases.

To ensure that its goal can be achieved, WADE undertakes a growing range of research and other actions on behalf of its supporters and members:

- WADE carries out promotional activities and research to document all aspects of DE, including policy, regulatory, economic and environmental aspects in key countries and regions.
- WADE works to extend the international network of national DE and cogeneration organisations. Current WADE network members represent Europe, the USA, India, China and Brazil.
- WADE provides a forum for DE companies and organisations to convene and communicate.
- WADE jointly produces an industry journal – "Cogeneration and On-Site Power" (published by James & James in association with WADE).

This report was researched and written by Aurelie Morand, Research Executive, WADE, aurelie.morand@localpower.org.

Further information about WADE is available at www.localpower.org or by contacting:

Michael Brown
Director
WADE
15 Great Stuart Street
Edinburgh, EH3 7TP, UK
+44 131 625 3333, fax 3334
michael.brown@localpower.org

Thomas R. Casten – Chairman of WADE
Chairman & CEO
Primary Energy LLC
2000 York Road, Suite 129
Oak Brook, Il 60523, USA
+1 630 371 0505, fax 0673
tcasten@primaryenergy.com

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Main Findings

DE can meet demand growth at lower cost than central generation

In every scenario, DE[1] is able to meet new demand growth requirements in China with both lower capital and retail costs than central generation (CG).

The main reason is that DE requires less transmission and distribution (T&D)

The T&D network has high capital, operations and maintenance costs as well as significant energy losses. Unlike CG, DE is sited close to demand, so electricity flows shorter distances to customers, greatly reducing the need for T&D investment. The scale of the retail and capital cost benefits of DE is shown in figures 1 and 2 – clearly showing the costs associated with T&D. Compared to the high CG scenario, the high DE scenario cuts retail costs by 28% and capital costs by 38% - a saving of $400 billion[2] over the period to 2021.

Figure 1: Retail Costs in the Reference Scenario

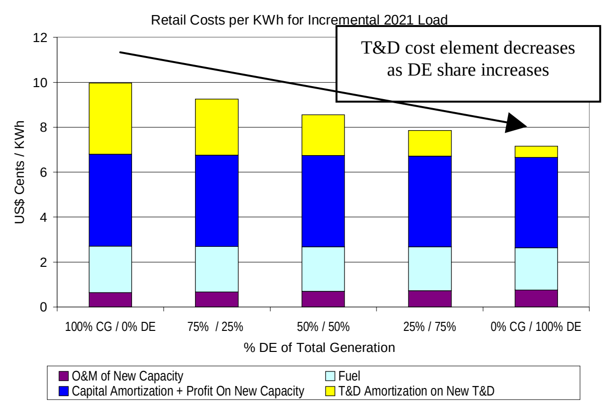
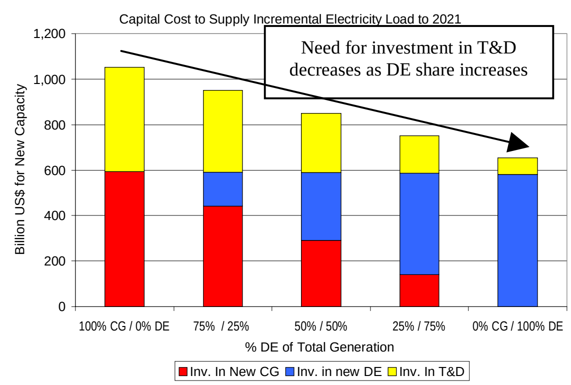


Figure 2: Capital Costs in the Reference Scenario



Both: WADE, 2004

[1] Decentralized energy includes: high efficiency cogeneration, on-site renewable energy and energy recycling.
[2] US$1 = Yuan 8.28 Renminbi on 2 Dec. 04

The high DE scenario also cuts emissions

Since DE is less fossil fuel intensive than CG, the high DE scenario greatly reduces emissions. Emissions of CO_2 are 56% less than in the high CG scenario, and emissions of NOx and SOx are cut by 89%.

Other Key Findings

WADE undertook a wide range of scenario analyses to explore the impact of different factors.

Main findings include:

- **Typical financing periods in China are only ten years. Doubling the period of financing from 10 to 20 years cuts retail costs by up to 20%.**

- **Use of nuclear power is not necessary to deliver major carbon emission reductions.**
  CO_2 emissions in the high CG Low Carbon Scenario are higher than emissions in the high DE Reference Scenario. Lowest emissions of all are the in the high DE Low Carbon Scenario. The nuclear option is not necessary to bring about CO_2 reductions.

- **The major cost benefits of gas-fired DE are not jeopardised by gas price concerns.** Doubling of gas prices has little impact on overall retail costs in any scenario.

- **The impacts of reducing rates of electricity demand growth are immense.** A demand growth rate of 3% cuts the capital cost requirement by 49% compared to the Reference growth rate of 4.8%.

The WADE Economic Model

The purpose of the WADE Economic Model is to calculate the economic and environmental impacts of supplying incremental electric load growth with varying mixes of central (CG) and Decentralized (DE) generation. With changed input assumptions, the Model can be adapted to any country, city or region in the world. Starting with generating capacity for the current or recent year, together with estimates of retirement rates and load growth, the model builds user-specified capacity to meet new requirements over a 20 year period.

The Model's data input requirements are detailed and extensive, requiring comprehensive information on a range of factors including:

- Existing capacity and generation by technology type
- Pollutant emissions by technology type
- Heat rates, fuel consumption and load factor by technology type
- Capital and investment costs by technology type and for transmission and distribution (T&D)
- Average operation and maintenance (O&M) and fuel expenses by technology type
- System growth properties for the chosen system
- Estimates of existing yearly capacity retirement by technology type
- Estimates of future growth in capacity by technology type

The completed input sheet for the China Reference Scenario can be found in Annex A, with the sources for the inputs used detailed in Annex B. Annex C contains the assumptions used for each generation portfolio scenario that was run for the purposes of this study.

The Model outputs are:

- Total capital costs for investment (generation capacity + T&D) over 20 years
- Retail costs in year 20 (T&D amortisation + generation plant amortisation + O&M + fuel costs) for the new generation capacity
- Fossil fuel use by the new capacity in year 20
- CO_2 and other pollutant (SO_2, NO_x, PM_{10}) emissions from new generation capacity in year 20.

The Model builds new generation and T&D capacity to meet incremental demand over 20 years, ranging from scenarios with 0% DE / 100% CG to 100% DE / 0% CG. The model also builds cases between these extremes. The Model also enables users to run any number of scenarios that, for example, favour certain technologies, change fuel prices or meet specific environmental goals. Such scenarios were applied to the run of the Model for China described in this report.

The Model takes into account many real but little understood features of electricity system operation. For example, it takes into account the significant impact of peak time network losses on the amount of CG required to meet new demand. Assuming peak T&D losses of 26.5% (the assumption used in the Reference Scenario), new demand of 1 MW can only be met by adding 1.35 MW of new CG.

For a full explanation of the WADE Economic Model, please consult the Model Description, available online at www.localpower.org.

To date, as well as China, the WADE Economic Model has been run for:

- Brazil
- The European Union (funded by the EU DG-Fer programme)
- Ireland (funded by the Republic of Ireland Government)
- The Canadian province of Ontario (funded by the Canadian federal government)
- Thailand (funded by the EU COGEN-3 programme)
- The USA
- The World

Of these, the main Model outputs are publicly available for Brazil, the European Union, Ontario and the World. Additionally, results for the USA are also publicly available, along with a paper explaining their derivation and significance. For more information on these results or the WADE Economic Model, please contact WADE.

Results for China

Scenario Descriptions

Reference Scenario

This scenario is based on data obtained for China for the year 2001 and on balanced assumptions for all other inputs over the period 2001 - 2021. The inputs used in this scenario are listed in Annex A.

Modelling Scenarios (1) – Demand Growth and Economic Conditions

The following scenarios were run for the purposes of this study:

- Low Electricity Demand Growth (3.0% compared to 4.8% in the Reference Scenario)
- High Electricity Demand Growth (8.0%)
- Double Gas Price (from US$ 3.91 / GJ for CG and US$ 5.87 / GJ for DE)
- Double Financing Term for T&D and generation technologies (from 10 years)
- High T&D Costs (increased by 33% from US$ 750 / kW in the Reference Scenario).

In each of these scenarios, only the named variable was changed; all other inputs remained as in the Reference Scenario.

Modelling Scenarios (2) – Generation Portfolios

The following scenarios, varying the future growth of China's generation portfolio, were also run:

- Low Carbon – increased share of nuclear (CG) and renewables (CG and DE) capacity
- High Gas Capacity – increased share of gas-fired capacity, both CG and DE
- High Coal Capacity – increased share of coal-fired capacity, both CG and DE.

The inputs used in each of these scenarios are listed in Annex C. Only future technology market shares were altered for these scenarios; all other inputs in the model remained as in the Reference Scenario.

Outputs - Reference Scenario

The graphs that follow show the scenario results for each of the four main outputs of the WADE Economic Model: Capital Costs; Retail Costs; Fossil Fuel Use; and Pollutant Emissions (CO_2, NO_x, SO_2, PM_{10}).[3]

The Model results that relate to economic aspects under the Reference Scenario are shown in Table 1. Under this scenario, building all incremental generating capacity to 2021 as DE would represent savings of US$400 billion over the 100% CG scenario. As a consequence, retail costs from new plant in a 100% DE scenario would also be significantly lower - US$c2.81 cheaper per kWh in 2021.

Table 1: Impact of Meeting Demand Growth to 2021 with CG or DE Generation; Reference Scenario

	100% CG Generation	100% DE Generation	DE Savings	% Savings
Total Capital Cost (Capacity + T&D) in Billions of US$	1,053	653	400	38%
Retail Cost ($c / kWh; new plant)	9.97	7.16	2.81	28%

WADE, 2004

Table 2 shows the impact of the two extreme scenarios on pollutant emissions. In the 100% DE scenario, emissions savings compared to the 100% central scenario range from 56% for CO_2 and 58% for PM_{10} to 89% for both NO_x and SO_2[4].

Table 2: Impact of Meeting Demand Growth to 2021 with CG or DE Generation; Reference Scenario

	100% CG Generation	100% DE Generation	DE Savings	% Change
Emissions (000 t)[5]:				
NO_x	917	99	819	89%
SO_2	910	97	813	89%
PM_{10}	48	20	28	58%
CO_2 Emissions (Mt)	739	322	416	56%

WADE, 2004

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[3] Throughout, references to scenarios labelled as "CG" and "DE" represent the extreme cases, where 100% of incremental generating capacity between years 1 and 20 is allocated to one or the other (i.e. 100% new CG or DE). In reality, it is highly unlikely that either situation will arise; the most likely scenario will be a CG / DE mix between these extremes.

It is also important to recognize that the 100% DE scenario implies that only incremental generating capacity in the 20 year period would be built as DE – not that *all* capacity is DE. The actual shares of DE and CG in year 20 would be a function of pre-existing generating capacity (at the start of year 1) and new capacity built (between years 1 and 20). WADE estimates that in the 100% DE scenario, the market share of CG in year 20 will be at least 40%.

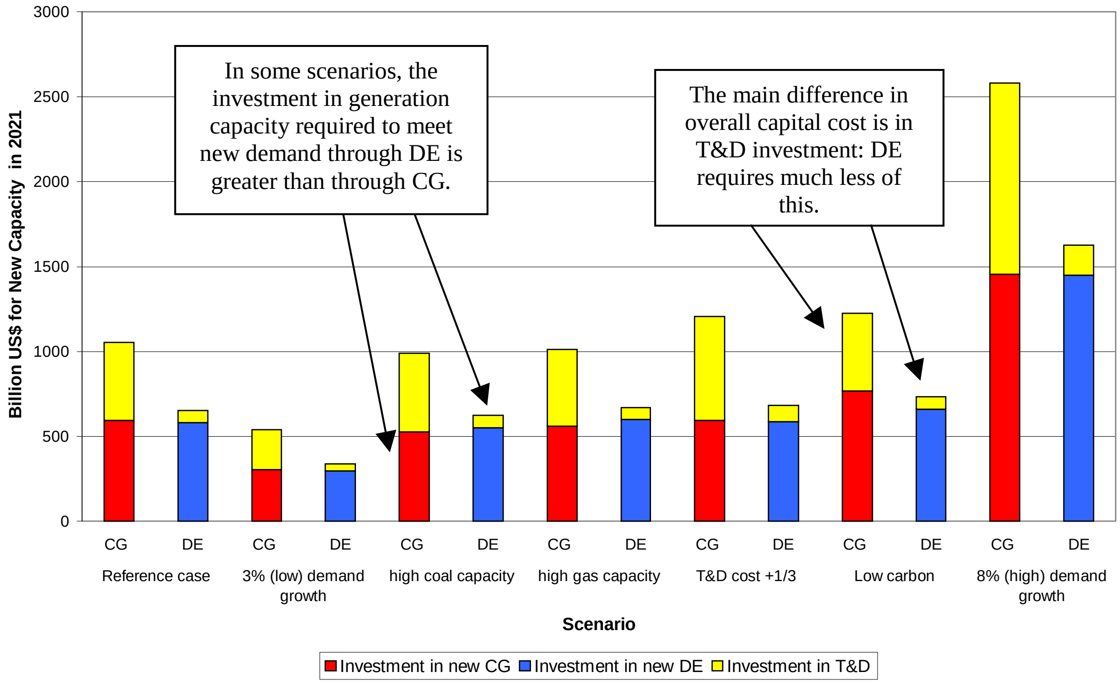
[4] The model takes account of emissions saved by CHP from displaced boiler plant.

[5] Figures rounded to the nearest whole number

Outputs – Modelling Scenarios

1. Impact on Capital Costs of Meeting Demand to 2021

Figure 3: Capital Costs of Meeting Incremental Demand in China to 2021 under Modelling Scenarios



WADE, 2004

- There is little difference between the High Coal, High Gas and Reference Scenarios.
- Increasing T&D costs affects CG much more than it affects DE – this is because CG needs more T&D than DE to meet the same electricity demand.
- The Low Carbon Scenario is the costliest generation portfolio scenario for both CG and DE.
- Electricity demand growth is the variable that most affects capital costs, as shown in Table 3. Reducing demand growth to 3.0% from 4.8% (in the Reference Scenario) would reduce the capital costs required to meet new demand by 49%. Demand growth also has the most effect on fuel use and CO_2 emissions, as seen in Figures 5 and 6 (pp. 13 and 14).

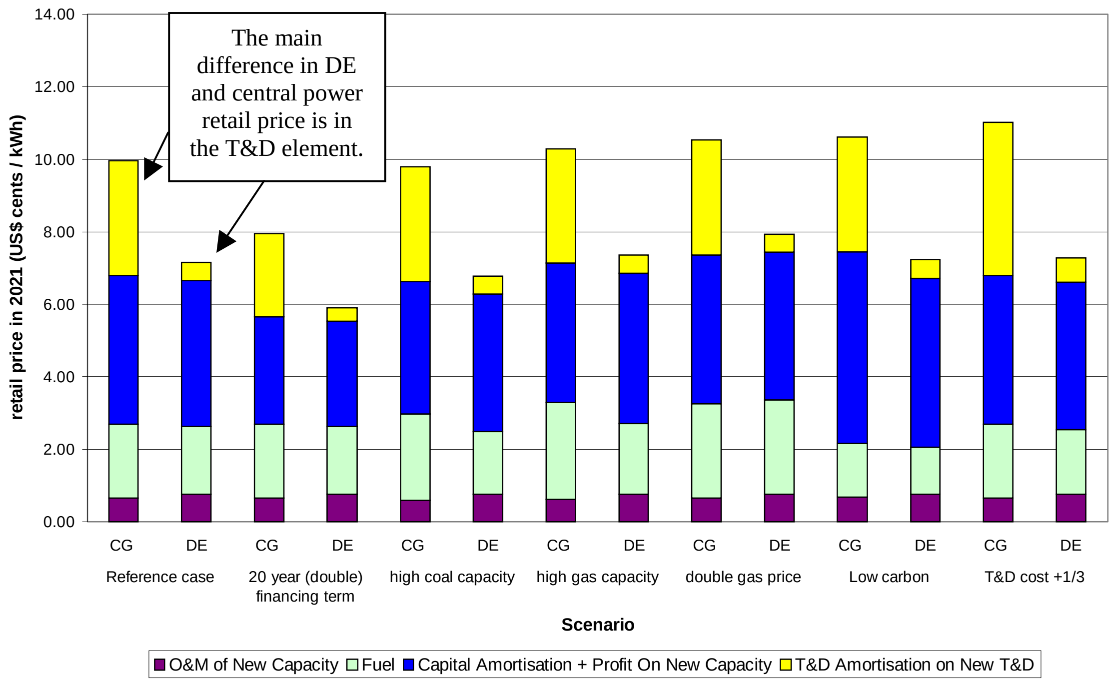
Table 3: Impact of Electricity Demand Growth on Capital Costs for 100% New DE and 100% New CG

Scenario	Annual Electricity Demand Growth	Electricity Demand Growth Relative to Reference	Capital Costs (bn US$)	Capital Costs Relative to Reference
		100% CG		
Low Demand	3.0%	-38%	538	-49%
Reference	4.8%	-	1,053	-
High Demand	8.0%	+67%	2,597	+147%
		100% DE		
Low Demand	3.0%	-38%	335	-49%
Reference	4.8%	-	653	-
High Demand	8.0%	+ 67%	1,625	+149%

WADE, 2004

2. Impact on Retail Costs

Figure 4: Retail Costs in China for Incremental 2021 Load under Modelling Scenarios



WADE, 2004

- Length of financing terms and T&D cost have the biggest impacts on retail costs.
- As DE requires less T&D than CG to meet demand growth, DE suffers less from increased T&D costs. The effects of T&D cost increase and financing term length on both CG and DE are summarised in Table 4.

Table 4: Impact of T&D Cost Increase and Financing Term on Retail Costs of Electricity from New Plant in China in 2021

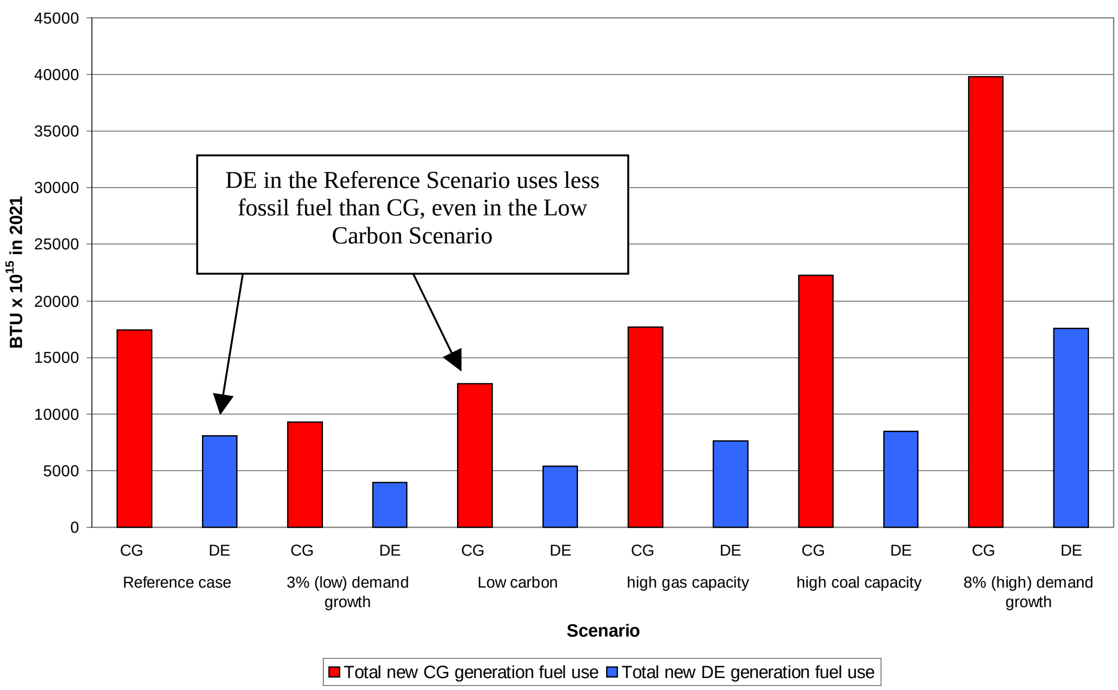
		Total Retail cost (US$ Cents / kWh)	DE cost advantage	Variance from Reference Scenario
Reference Scenario	100% CG	9.97	28%	-
	100% DE	7.16		
Double (20 yr) Financing Term	100% CG	7.95	26%	-20%
	100% DE	5.90		-18%
T&D Cost +1/3	100% CG	11.03	34%	+11%
	100% DE	7.27		+1.5%

WADE, 2004

- Doubling gas prices has little impact on overall fuel costs due to the small proportion of gas-fired generation – relative to coal – built into the Reference Scenario. Doubling gas prices in the High Gas Capacity Scenario would have a stronger impact.
- There is little difference between the High Gas Capacity and Reference Scenarios; the High Coal Scenario has slightly lower retail costs.
- The Low Carbon Scenario (increased shares of nuclear and renewables) has the highest retail costs of the generation portfolio scenarios for CG. The impact on the high DE scenario is less since there is no expensive nuclear power generation in DE.

3. Impact on Fossil Fuel Use

Figure 5: Fossil Fuel Use to Meet Incremental Demand in China to 2021 under Modelling Scenarios

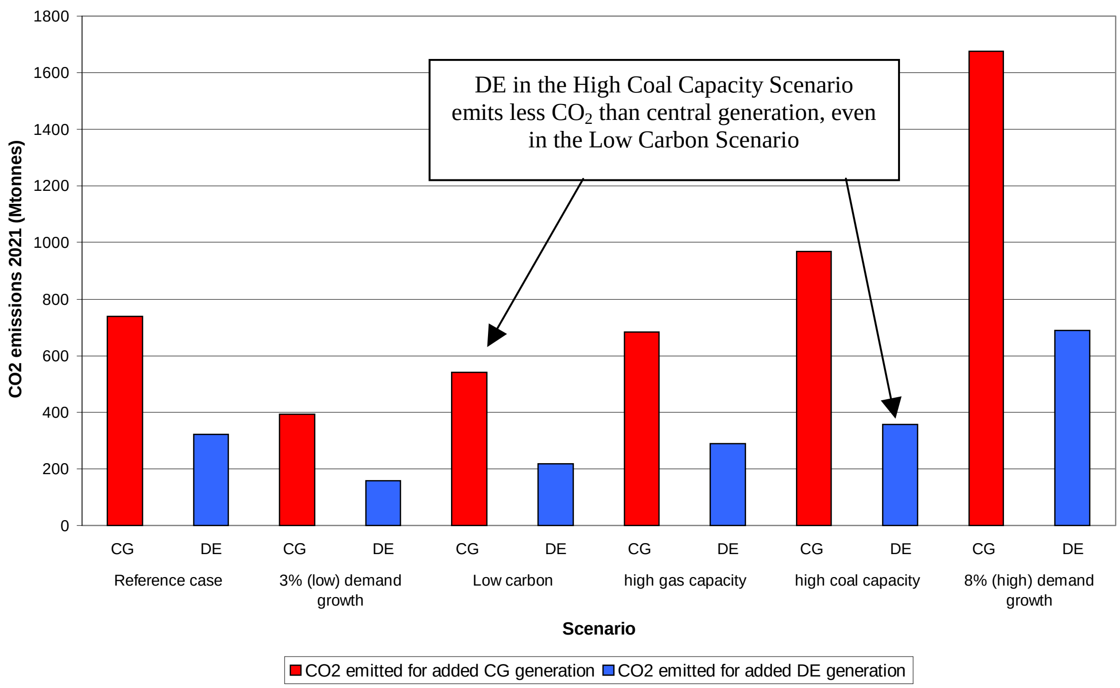


WADE, 2004

- In each of the scenarios, DE uses less fossil fuel than CG
- DE in the Reference Scenario consumes less fossil fuel than CG in the Low Carbon Scenario
- The High Coal Capacity Scenario uses more fossil fuel than any of the generation portfolio scenarios. This is because of the low conversion efficiency of coal-fired generation.
- The highest fossil fuel use occurs in the High Demand Growth Scenario.

4. Impact on CO_2 and Pollutant Emissions

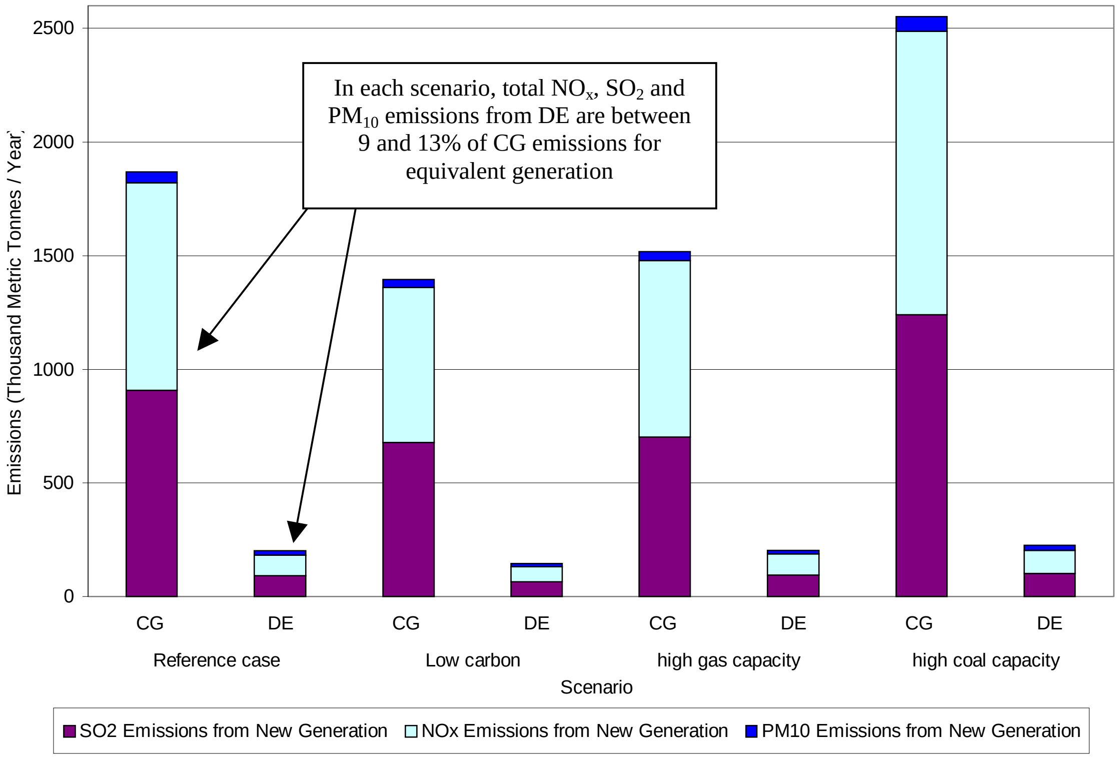
Figure 6: CO_2 Emissions from Incremental Capacity in China in 2021 under Different Scenarios



WADE, 2004

- In all cases, DE has lower CO_2 emissions than CG.
- DE in the High Coal Capacity Scenario emits less CO_2 than CG in the Low Carbon Scenario.

Figure 7: Pollutant Emissions from New Capacity in China in 2021 under Modelling Scenarios



WADE, 2004

- In the Reference and Low Carbon Scenarios, total NO_x, SO_2 and PM_{10} emissions from DE generation are around 10% of the emissions from corresponding CG (largely through boiler emissions offset by CHP plant).
- The advantage of DE in the High Gas Scenario is slightly smaller (13% of CG emissions).
- The advantage of DE in the High Coal Scenario is slightly higher (9% of CG emissions).

Key Conclusions

China could save up to US$400 billion by meeting incremental electricity demand growth to 2021 with DE.

100% use of DE to meet demand growth to 2021 will give capital cost savings of almost 40% compared to 100% use of CG.

Retail costs are significantly lower with DE

In the Reference Scenario, the 100% DE case leads to 28% lower retail costs than the corresponding CG case. DE retail costs are lower than CG retail costs in all scenarios.

The impact of the T&D cost is the key difference between CG and DE

DE requires significantly less T&D investment than CG to meet the same level of demand. In addition, DE is much less affected by rises in T&D costs. Both capital and retail costs for CG are strongly affected by rises in T&D costs.

DE provides a highly cost-effective solution for lowering CO_2 emissions

In the Reference Scenario, 100% use of DE produces CO_2 emissions that are 56% lower than 100% use of CG. Even in the High Coal Scenario, DE emits less CO_2 than CG in the Low Carbon Scenario.

Demand growth has the largest impact on capital costs, fossil fuel use and emissions.

This demonstrates the importance of end-use efficiency in controlling costs and environmental impacts of electricity generation.

Annexes

Annex A: Reference Scenario Input Sheet for China

Existing Capacity and Generation

	Installed Capacity GW	Load Factor %	Electricity Generation TWh	Future Load Factor %
CG - 2001				
Coal - Steam	240.160	53.4%	1,123.80	60.0%
Oil - steam	6.067	86.3%	45.89	80.0%
Oil- Comb. Turb.	0.000	0.0%	0.00	10.0%
Oil - Comb. Cyc.	0.000	0.0%	0.00	60.0%
Gas - Steam	5.814	48.7%	24.83	50.0%
Gas - Comb Turb	0.000	0.0%	0.00	10.0%
Gas Comb Cycle	0.000	0.0%	0.00	60.0%
Bioenergies	0.000	0.0%	0.00	75.0%
Hydro/ pump Stor.	82.700	38.3%	277.43	50.0%
Geothermal	2.300	50.0%	10.07	50.0%
Nuclear	2.100	95.0%	17.48	85.0%
Solar	0.000	0.0%	0.00	30.0%
Wind	0.399	29.0%	1.01	29.0%
	339.540		1500.51	
DE - 2001				
Coal CHP	29.293	50.0%	128.30	60.0%
Oil CHP	1.910	50.0%	8.37	60.0%
Gas CHP	0.637	50.0%	2.79	60.0%
Bioenergies CHP	0.000	0.0%	0.00	65.0%
Hydro (Local)	26.262	37.9%	87.10	38.0%
Solar (Local)	0.200	15.0%	0.26	30.0%
Wind (Local)	0.003	26.8%	0.01	27.0%
	294.667		226.83	

Heat Rates / Fuel Consumption - (kJ/kWh) LHV

	existing mix KJ / kWh	Future Plants KJ / kWh	Fossil ?	CO2 Factor	CO2, lb/MMBtu (LHV)
CG					
Coal - Steam	11,000	10,300	yes	Coal - Average	206.858
Oil - steam	11,000	10,300	yes	Heavy Fuel Oil	184.120
Oil- Comb. Turb.	14,000	9,000	yes	Heavy Fuel Oil	184.120
Oil - Comb. Cyc.	7,500	6,000	yes	Heavy Fuel Oil	184.120
Gas - Steam	11,000	10,300	yes	Natural Gas	129.415
Gas - Comb Turb	13,000	9,000	yes	Natural Gas	129.415
Gas Comb Cycle	7,000	6,000	yes	Natural Gas	129.415
Bioenergies	12,000	11,000	no	Wood / biomass	0.000
Hydro/ pump Stor.	0	0	no	none	0.000
Geothermal	0	0	no	none	0.000
Nuclear	0	0	no	none	0.000
Solar	0	0	no	none	0.000
Wind	0	0	no	none	0.000
DE					
Coal CHP	5,250	4,550	yes	Coal - Average	206.858
Oil CHP	7,000	4,550	yes	Heavy Fuel Oil	184.120
Gas CHP	5,250	4,550	yes	Natural Gas	129.415
Bioenergies CHP	8,000	6,000	no	Wood / biomass	0.000
Hydro (Local)	0	0	no	none	0.000
Solar (Local)	0	0	no	none	0.000
Wind (Local)	0	0	no	none	

Capital / Investment Costs

	2001 Installed Cost (US$/ KW)	Avg. Yearly Cost Increase (Reduction) US$	Cost / kW in 2021 US$	Return on Capital %	Financing Term years
CG					
Coal - Steam	600	0%	600	10%	10
Oil - steam	700	1%	854	10%	10
Oil- Comb. Turb.	377	1%	460	10%	10
Oil - Comb. Cyc.	600	1%	732	10%	10
Gas - Steam	700	1%	854	10%	10
Gas - Comb Turb	400	0%	400	10%	10
Gas Comb Cycle	600	1%	732	10%	10
Bioenergies	1,250	-1%	1,022	10%	10
Hydro/ pump Stor.	1,100	1%	1,342	10%	10
Geothermal	1,500	-1%	1,275	10%	10
Nuclear	1,700	0%	1,700	10%	10
Solar	4,000	-5%	1,434	10%	10
Wind	950	-1%	777	10%	10
DE					
Coal CHP	700	0%	700	10%	10
Oil CHP	700	0%	700	10%	10
Gas CHP	950	1%	1,159	10%	10
Bioenergies CHP	1,500	-1%	1,227	10%	10
Hydro (Local)	850	1%	1,037	10%	10
Solar (Local)	5,000	-5%	1,792	10%	10
Wind (Local)	850	-1%	695	10%	10

T&D	US$ / KW
T&D	750
Assumed Return on Capital	10%
Financing Term	10 Years

Future Growth Determination

Model assumption is that future "growth" KWh's are met by given proportions

DE Growth as a % of market share will be shown for various scenarios

	Existing % of Generation	New Capacity Generation % for year 1	New Capacity Generation % for year 20
CG			
Coal - Steam	74.89%	77%	35%
Oil - steam	3.06%	1%	0%
Oil- Comb. Turb.	0.00%	0%	0%
Oil - Comb. Cyc.	0.00%	0%	0%
Gas - Steam	1.65%	1%	0%
Gas - Comb Turb	0.00%	0%	4%
Gas Comb Cycle	0.00%	2%	15%
Bioenergies	0.00%	0%	5%
Hydro/ pump Stor.	18.49%	13%	13%
Geothermal	0.67%	0%	3%
Nuclear	1.16%	4%	15%
Solar	0.00%	0%	0%
Wind	0.07%	2%	10%
	100%	100%	100%
DE			
Coal CHP	56.56%	80%	33%
Oil CHP	3.69%	2%	2%
Gas CHP	1.23%	5%	32%
Bioenergies CHP	0.00%	1%	15%
Hydro (Local)	38.40%	10%	10%
Solar (Local)	0.12%	1%	7%
Wind (Local)	0.00%	1%	1%
	100%	100%	100%

Pollution

	Current ppm	Future (exist. equip) ppm	Future (New Equip) ppm	2001 / current kg/ MWh	Future - Existing kg/ MWh	Future - New kg/ MWh
NOx						
CG						
Coal - Steam	487	400	100	3.36	2.76	0.65
Oil - steam	847	400	100	3.77	1.78	0.42
Oil- Comb. Turb.	723	400	100	13.87	7.67	NA
Oil - Comb. Cyc.	75	45	5	0.77	0.46	NA
Gas - Steam	708	400	100	3.29	1.86	0.43
Gas - Comb Turb	60	25	5	1.07	0.45	0.06
Gas Comb Cycle	60	25	5	0.58	NA	0.04
Bioenergies	60	25	5	0.00	0.00	0.00
DE						
Coal CHP	200	100	20	0.66	0.33	0.06
Oil CHP	75	45	10	0.72	0.43	0.06
Gas CHP	60	25	10	0.43	0.18	0.06
Bioenergies CHP	500	400	100	0.00	0.00	0.00
SO2						
CG						
Coal - Steam	840	400	100	5.80	2.76	0.65
Oil - steam	220	400	100	0.98	1.78	0.42
Oil- Comb. Turb.	3,927	400	100	75.34	7.67	NA
Oil - Comb. Cyc.	10	5	5	0.10	0.05	NA
Gas - Steam	4	4	4	0.02	0.02	0.02
Gas - Comb Turb	4	4	4	0.07	0.07	0.05
Gas Comb Cycle	4	4	4	0.04	NA	0.03
Bioenergies	4	4	4	0.00	0.00	0.00
DE						
Coal CHP	100	50	20	0.33	0.16	0.06
Oil CHP	10	5	5	0.10	0.05	0.03
Gas CHP	12	10	10	0.09	0.07	0.06
Bioenergies CHP	8	5	5	0.00	0.00	0.00
PM10						
CG						
Coal - Steam	13	10	5	0.20	0.15	0.07
Oil - steam	13	10	5	0.13	0.10	0.05
Oil- Comb. Turb.	4	4	1	0.18	0.17	NA
Oil - Comb. Cyc.	5	4	1	0.10	0.09	NA
Gas - Steam	6	2	1	0.06	0.02	0.01
Gas - Comb Turb	6	2	1	0.24	0.08	0.03
Gas Comb Cycle	5	2	1	0.11	NA	0.02
Bioenergies	5	5	1	0.00	0.00	0.00
DE						
Coal CHP	11	5	5	0.08	0.04	0.03
Oil CHP	5	2	1	0.11	0.04	0.01
Gas CHP	5	2	1	0.08	0.03	0.01
Bioenergies CHP	15	10	5	0.00	0.00	0.00

Existing Capacity Yearly Retirement Determination

Base Year 2001

	Current GC Capacity GW	CG Retirements MW	% Retirement in Year 1
CG			
Coal - Steam	240.160	100.00	0.042%
Oil - steam	6.067	32.00	0.527%
Oil- Comb. Turb.	0.000	0.00	0.000%
Oil - Comb. Cyc.	0.000	0.00	0.000%
Gas - Steam	5.814	0.14	0.002%
Gas - Comb Turb	0.000	0.00	0.000%
Gas Comb Cycle	0.000	0.00	0.000%
Bioenergies	0.000	0.00	0.000%
Hydro/ pump Stor.	82.700	2.00	0.002%
Geothermal	2.300	1.00	0.043%
Nuclear	2.100	0.00	0.000%
Solar	0.000	0.00	0.000%
Wind	0.399	0.00	0.000%
	339.540	135.14	0.040%
DE			
Coal CHP	29.293	19.00	0.065%
Oil CHP	1.910	7.20	0.377%
Gas CHP	0.637	0.03	0.005%
Bioenergies CHP	0.000	0.00	0.000%
Hydro (Local)	26.262	125.00	0.476%
Solar (Local)	0.200	5.00	2.500%
Wind (Local)	0.003	0.00	0.004%
	294.667	156.23	0.053%
TOTAL Yearly Retirement			291.3701

Average Operating, Maintenance, & Fuel Expenses

	O & M (Current Plants) tenths of US cent / KWh	O & M (Future Plants) tenths of US cent / KWh	O & M Improvements (Future Plants) Annualized Increase (Reduction)	Fuel Cost US$ / GJ	Fuel Cost Annualized Increase (Reduction)
CG					
Coal - Steam	4.5	4.5	0%	1.03	4%
Oil - steam	4.0	4.0	0%	1.50	4%
Oil- Comb. Turb.	4.0	4.0	0%	1.50	4%
Oil - Comb. Cyc.	6.0	6.0	0%	1.50	4%
Gas - Steam	4.0	4.0	0%	3.91	2%
Gas - Comb Turb	6.0	6.0	0%	3.91	2%
Gas Comb Cycle	4.0	4.0	0%	3.91	2%
Bioenergies	7.0	7.0	0%	0.75	0%
Hydro/ pump Stor.	6.5	6.5	0%	0.00	0%
Geothermal	8.0	8.0	0%	0.00	0%
Nuclear	10.0	10.0	0%	1.94	0%
Solar	2.0	2.0	0%	0.00	0%
Wind	6.0	6.0	0%	0.00	0%
DE					
Coal CHP	8.0	8.0	0%	1.86	4%
Oil CHP	6.0	6.0	0%	1.70	4%
Gas CHP	7.2	7.2	0%	5.87	2%
Bioenergies CHP	8.0	8.0	0%	1.00	0%
Hydro (Local)	8.5	8.5	0%	0.00	0%
Solar (Local)	3.0	3.0	0%	0.00	0%
Wind (Local)	8.0	8.0	0%	0.00	0%

System Growth Properties

				T &D 2004 safety	0%
Annualized Demand Growth	4.80%			T &D 2006 safety	0%
Annualized Peak Growth	5.33%			T &D 2008 safety	0%
Year to be Analyzed	2021	CO2 Mid Term Analysis	2011	T &D 2010 safety	0%
Avg.T&D Losses	15.0%			T &D 2012 safety	0%
Peak Tran.. & Dist Losses	26.5%			T &D 2014 safety	0%
Safety / Outage Levels		DE Peak Deliverability Penalty	3%	T &D 2016 safety	0%
Coincident Peak %	0.9	Coincident Peak divided by Non-coincident total load		T &D 2018 safety	0%
CG Safety Margin	15.0%			T &D 2020 safety	0%
T&D Safety Margin	20.0%			T &D 2021 safety	0%
DE Safety Margin	10.0%				
DE random Outage	20.0%				

WADE, 2004

Annex B: Sources for Data for the WADE Economic Model Reference Scenario Run for China - All figures for 2001, except fuel prices taken as current

Generation Capacity

CG

Coal ST	2000 breakdown (APEC) applied to 2001 total (LBL)
Oil ST	
Gas ST	
Nuclear	LBL
HEP & Pumped Storage	LBL
Geothermal	1999 (DTI) reviewed upwards pro rata.
Wind	DTI

DE

Coal CHP	Total CHP capacity 2001 (APEC). Broken down: 92% coal, 6% oil, 2% gas, 0% bio-energies (approx. Peak Pacific)
Oil CHP	
Gas CHP	
Hydro (Local)	SHA China
Solar (Local)	DTI
Wind (Local)	DTI

Electricity Generation

CG

Coal ST	Total fossil generation (LBL); broken down on assumption that coal (in ST) c. 92% of fossil fuel input, oil (in ST) c. 6% and gas c. 1%; electricity generation calculated pro rata.
Oil ST	
Gas ST	
Nuclear	LBL
HEP & Pumped Storage	APEC and LBL
Geothermal	DTI (estimate)
Wind	Calculated using 29% LF and installed capacity

DE

Coal CHP	Assumed 50% LF; applied to existing capacity and worked out as for CG.
Oil CHP	
Gas CHP	
Hydro (Local)	SHA China
Solar (Local)	DTI (estimate)
Wind (Local)	LF calculated using 1998 figures for capacity and generation; applied LF to 2001 capacity.

System Growth

T&D Losses	LBL (country average)
Peak T&D Losses	Ratio between T&D losses and Peak T&D losses (*1.765) applied to Chinese T&D losses.
Central Safety Margin	Same as USA
Annual Electricity Demand Growth	Average - EIA International Energy Outlook and PNL
Annualized Peak Growth	Ratio between demand growth and peak growth (*1.1) applied to Chinese demand growth
T&D Safety Margin	Same as USA
Coincident Peak %	
DE Safety Margin	
Central Safety Margin	
DE random Outage	USA assumed figure is 3%; applied a factor of 6.66 to derive the figure for China based on a less mature network development in China
T&D Safety Years 1-20	0% for each year

Capital Costs

T&D

T&D	US Fig revised downwards for China
T&D Financing Term	Peak Pacific (Kent Carter)

CG

Coal ST	Peak Pacific (Kent Carter)
Oil ST	Estimate (WADE)
Oil CT	Estimate (WADE)
Oil CC	Same fig as gas CC
Gas ST	Estimate (WADE)
Gas CT	MIT
CCGT	MIT
Nuclear	Average MIT and BMI
HEP & Pumped Storage	Average BMI and PNL
Geothermal	Estimate (WADE)
Bioenergies	
Solar	BMI figure, revised downwards (WADE)
Wind	PNL
Plant Financing Terms	Peak Pacific (Kent Carter)

DE – DE capital costs are not based on marginal costs i.e. no allowance is made for cost of boiler replacement. The marginal cost basis would reduce capital costs of DE plant.

Coal CHP	Peak Pacific (Kent Carter)+ allowance for heat networks
Oil CHP	Estimate (WADE), relative to coal CHP
Gas CHP	CPG (Fred Yang) [average]
Bioenergies	Estimate (WADE), relative to coal CHP
Hydro (Local)	BMI
Solar (Local)	Estimate (WADE)
Wind (Local)	Wind farm cost (PNL) revised downwards as China is a market leader in small-scale turbines and these are manufactured domestically
Plant Financing Terms	Peak Pacific (Kent Carter)

O&M and Fuel

O&M CG

Coal ST	Peak Pacific (Kent Carter)
Oil ST	Estimate (WADE) – US figures revised strongly downwards
Oil CT	
Oil CC	
Gas ST	
Gas CT	
CCGT	
Nuclear	
HEP & Pumped Storage	
Geothermal	
Bioenergies	
Solar	
Wind	

Fuel CG

Coal ST	Peak Pacific (Roy Dean): 250 RMB / tonne of coal; 29.27 GJ / tonne of coal i.e. US$1.031 / GJ of coal.
Oil ST	Estimate (WADE) – US figures revised strongly downwards
Oil CT	
Oil CC	
Gas ST	DE gas price (CPG) reduced by 33%
Gas CT	
CCGT	
Nuclear	PNL
Bioenergies	Estimate (WADE)

O&M DE

Coal CHP	Peak Pacific (Kent Carter)
Oil CHP	Estimate (WADE)
Gas CHP	CPG (Fred Yang) [average]
Bioenergies	Estimate (WADE)
Hydro (Local)	
Solar (Local)	
Wind (Local)	

Fuel DE

Coal CHP	CPG (Fred Yang) US$56 / tonne; 27 GJ / tonne of coal i.e. US$1.86 / GJ of coal.
Oil CHP	Estimate (WADE)
Gas CHP	CPG (Fred Yang) US$0.229 / m^3; 0.039GJ / m^3 i.e. US$ 5.87 / GJ
Bioenergies	Estimate (WADE)

Retirement rates

CG

Coal ST	Estimate (WADE)
Oil ST	
Oil CT	
Oil CC	
Gas ST	
Gas CT	
CCGT	
Nuclear	Year 1: 0. Average age of plant is about 5 years (4*1year and 3*10 year in 2003) (CEA)
HEP & Pumped Storage	Estimate (WADE)
Geothermal	
Bioenergies	
Solar	
Wind	Estimate (WADE)

DE

Coal CHP	Estimate (WADE)
Oil CHP	
Gas CHP	
Bioenergies	
Hydro (Local)	
Solar (Local)	
Wind (Local)	

Heat rates and fuel consumption – current and future

CG

Coal ST	Peak Pacific (Roy Dean)
Oil ST	Same as for USA
Oil CT	
Oil CC	
Gas ST	
Gas CT	
CCGT	
Bioenergies	

DE

Coal CHP	Peak Pacific (Roy Dean)
Oil CHP	Same as for USA
Gas CHP	
Bioenergies	

Pollution

All	Same ppm as for all other runs of the model.

Future Load Factors

CG

All	Estimates (WADE)

DE

All	Estimates (WADE)

Sources:

APEC	Asia Pacific Economic Cooperation "*Energy Database*"
BMI	Battelle Memorial Institute, Logan et al "*China's Electric Power Options: An Analysis of Economic and Environmental Costs*"
CEA	French Atomic Energy Commission "*World Market for Nuclear Energy*" Presentation
CPG	Cummins Power Generation; Pers. Comm. Fred Yang
DTI	UK Department of Trade and Industry "*UK-China Renewables*" website
EIA	US Energy Information Administration "*International Energy Outlook*"
LBL	Lawrence Berkeley National Laboratory "*China Energy Databook, v.6.0*", June 2004
MIT	Massachusetts Institute of Technology, USA
Peak Pacific	Pers. Comm. Roy Dean, Kent Carter
PNL	Pacific Northwest Laboratory (DOE, USA)
SHA China	Chinese Small Hydropower Association

Abbreviations:

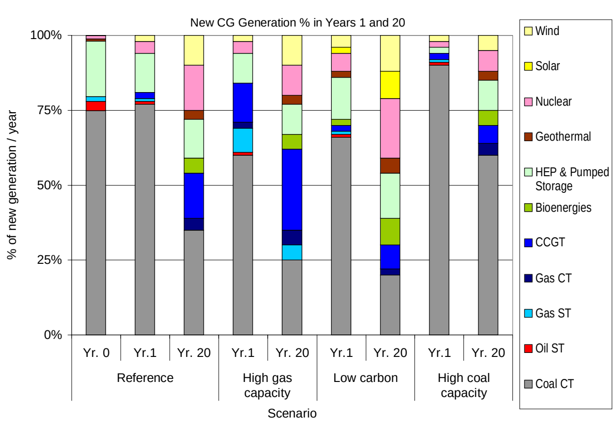
CC	Combined Cycle
CCGT	Combined Cycle Gas Turbine
CG	Central Generation
CHP	Combined Heat and Power (Cogeneration)
CT	Combustion Turbine
DE	Decentralised Energy
HEP	Hydro-Electric Power
LF	Load Factor
O&M	Operation and Maintenance
ST	Steam Turbine
T&D	Transmission and Distribution

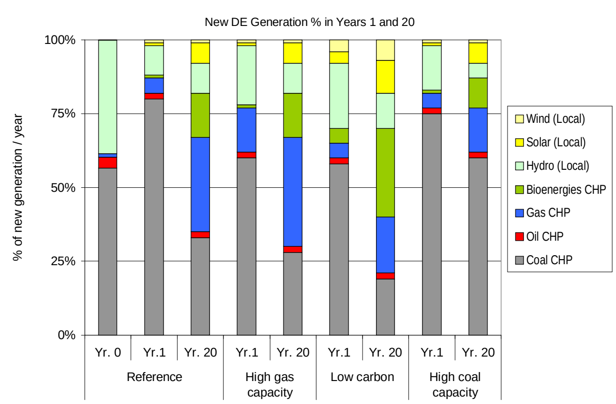
Annex C (a): Numerical Assumptions for Future Growth Determination

	Reference			High Gas Capacity		Low Carbon		High Coal Capacity	
	Existing % of Total Generation	New Capacity Generation % for Year 1	New Capacity Generation % for Year 20	New Capacity Generation % for Year 1	New Capacity Generation % for Year 20	New Capacity Generation % for Year 1	New Capacity Generation % for Year 20	New Capacity Generation % for Year 1	New Capacity Generation % for Year 20
100% CG									
Coal ST	**74.9%**	77.0%	35.0%	60.0%	25.0%	66.0%	20.0%	90.0%	60.0%
Oil ST	**3.1%**	1.0%	0.0%	1.0%	0.0%	1.0%	0.0%	1.0%	0.0%
Oil CT	**0.0%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Oil CC	**0.0%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gas ST	**1.7%**	1.0%	0.0%	8.0%	5.0%	1.0%	0.0%	1.0%	0.0%
Gas CT	**0.0%**	0.0%	4.0%	2.0%	5.0%	0.0%	2.0%	0.0%	4.0%
CCGT	**0.0%**	2.0%	15.0%	13.0%	27.0%	2.0%	8.0%	2.0%	6.0%
Bio-energies	**0.0%**	0.0%	5.0%	0.0%	5.0%	2.0%	9.0%	0.0%	5.0%
HEP & Pumped Storage.	**18.5%**	13.0%	13.0%	10.0%	10.0%	14.0%	15.0%	2.0%	10.0%
Geothermal	**0.7%**	0.0%	3.0%	0.0%	3.0%	2.0%	5.0%	0.0%	3.0%
Nuclear	**1.2%**	4.0%	15.0%	4.0%	10.0%	6.0%	20.0%	2.0%	7.0%
Solar	**0.0%**	0.0%	0.0%	0.0%	0.0%	2.0%	9.0%	0.0%	0.0%
Wind	**0.1%**	2.0%	10.0%	2.0%	10.0%	4.0%	12.0%	2.0%	5.0%
100% DE									
Coal CHP	**56.6%**	80.0%	33.0%	60.0%	28.0%	58.0%	19.0%	75.0%	60.0%
Oil CHP	**3.7%**	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%	2.0%
Gas CHP	**1.2%**	5.0%	32.0%	15.0%	37.0%	5.0%	19.0%	5.0%	15.0%
Bio-energies CHP	**0.0%**	1.0%	15.0%	1.0%	15.0%	5.0%	30.0%	1.0%	10.0%
Hydro (Local)	**38.4%**	10.0%	10.0%	20.0%	10.0%	22.0%	12.0%	15.0%	5.0%
Solar (Local)	**0.1%**	1.0%	7.0%	1.0%	7.0%	4.0%	11.0%	1.0%	7.0%
Wind (Local)	**0.0%**	1.0%	1.0%	1.0%	1.0%	4.0%	7.0%	1.0%	1.0%

WADE, 2004

Annex C (b): Graphs of Future Growth Determination





WADE, 2004

WADE

15 Great Stuart Street

Edinburgh

EH3 7TP

Scotland, UK

Tel: +44 131 625 3333

Fax: +44 131 625 3334

info@localpower.org

www.localpower.org

WADE

WORLD ALLIANCE FOR DECENTRALIZED ENERGY