Integrated Energy and Emission Scenario up to 2050 for China
2050年中国综合能源与排放情景

Low Carbon, Low pollution
低碳、低污染

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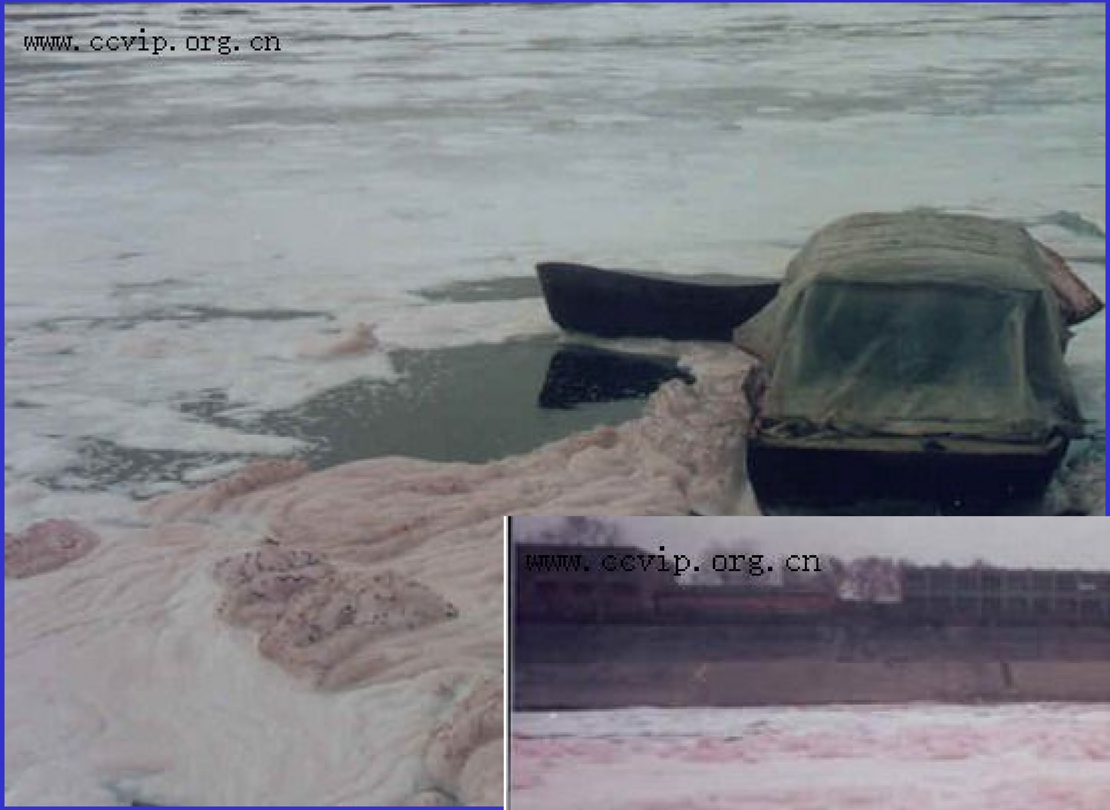
The 5th Air Quality Management City Workshop of CAI-Asia China Network, Beijing
第五届中国城市空气质量管理研讨会

北京

北京

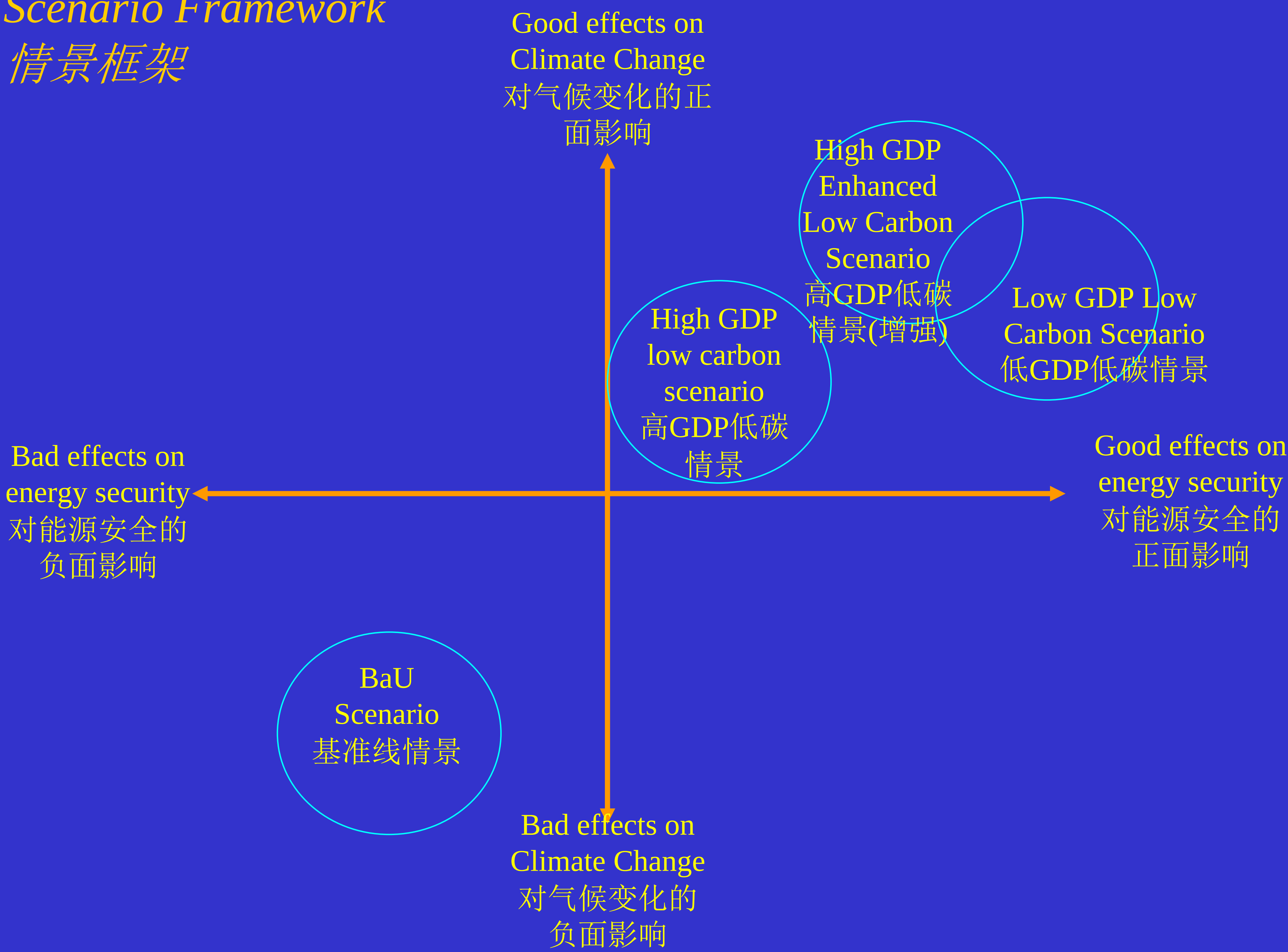
水污染



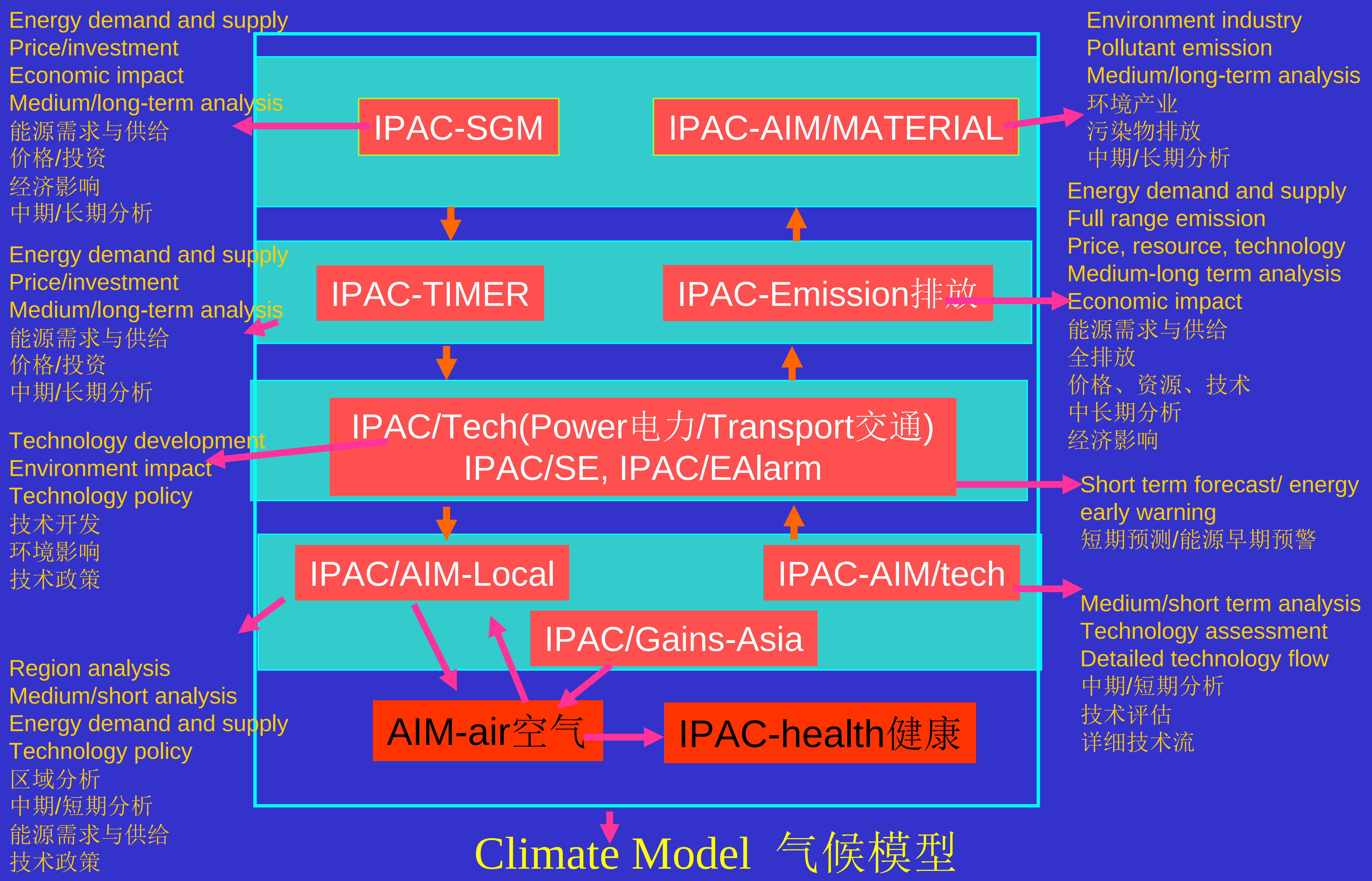
Low Carbon/Green Future: our vision
低碳/绿色未来:我们的愿景

- Low carbon/GHG emission
- 低碳/温室气体排放
- Comfortable life/high welfare
- 舒适的生活/高福利
- Green/eco-friendly development
- 绿色/经济友好型发展
- Well developed transport system with focus on easy walking/bicycle
- 发达的交通系统，便捷的步行和自行车出行
- Environment friendly life style
- 环境友好型生活方式
- Promote economy development
- 促进经济发展

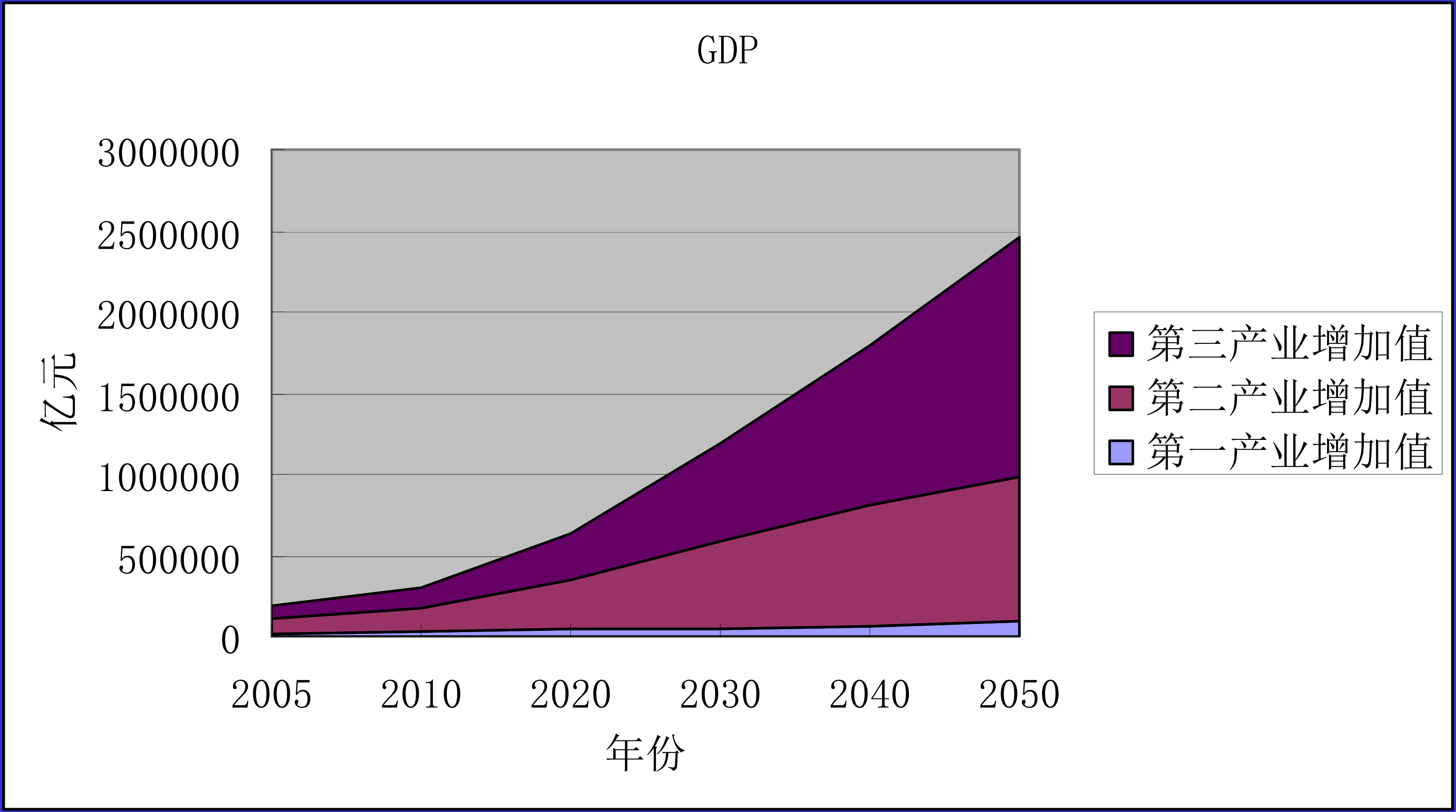
Scenario Framework
情景框架



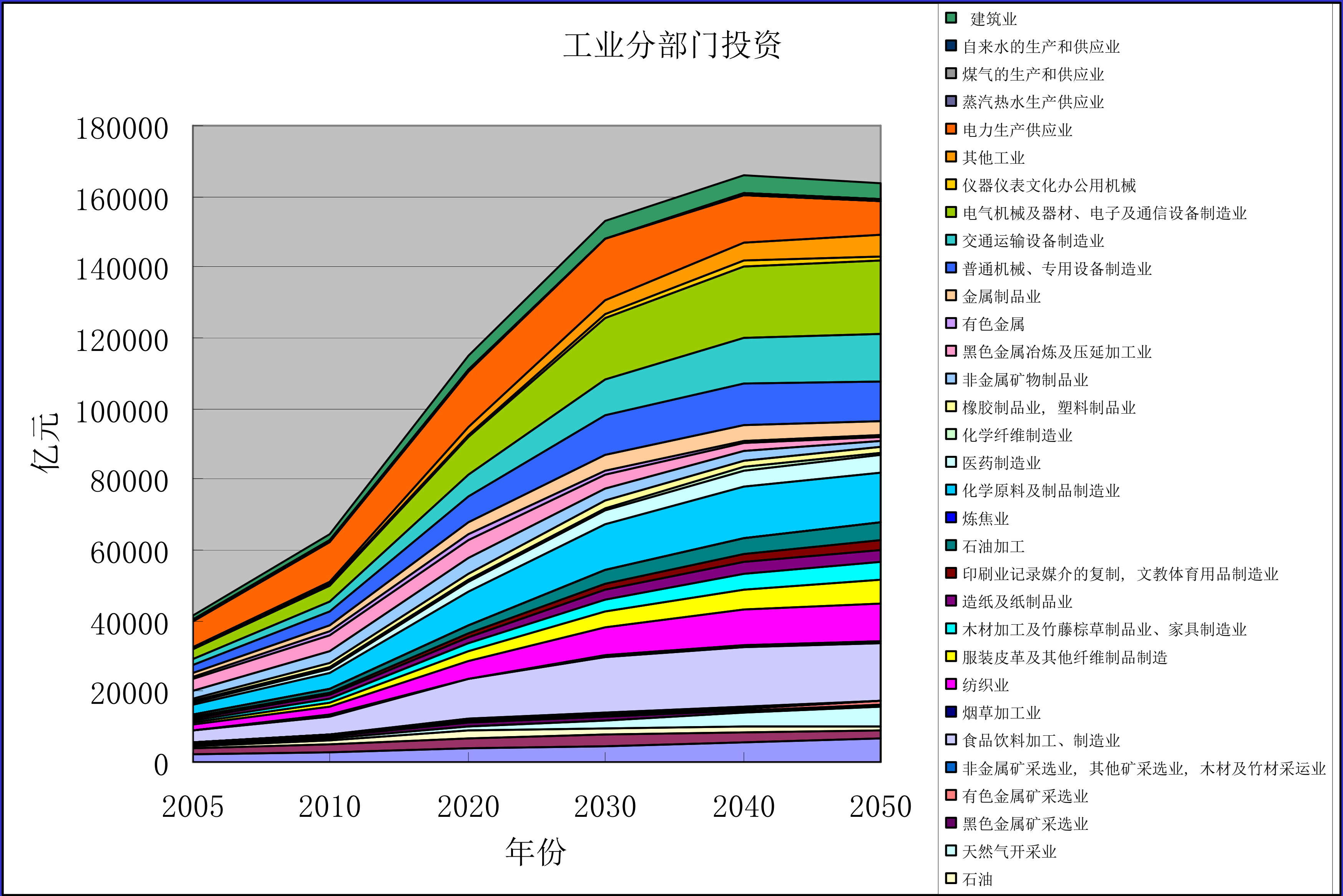
Framework of Integrated Policy Model for China (IPAC)中国综合政策模型框架（IPAC



Methodology framework
方法框架


GDP
3000000
2500000
2000000
1500000
1000000
500000
0
亿元
2005
2010
2020
2030
2040
2050
年份
第三产业增加值
第二产业增加值
第一产业增加值

Investment by industrial sectors
分行业的投资



Products output in major sectors, Low Carbon and ELC
主要部门的产品产量，低碳与ELC 情景

	Unit	2005	2020	2030	2040	2050
Steel	Million ton	355	610	570	440	360
Cement	Million ton	1060	1600	1600	1200	900
Glass	Million cases	399	650	690	670	580
Copper	Million ton	2.6	7	7	6.5	4.6
Ammonia	Million ton	8.51	16	16	15	12
Ethylene	Million ton	5.1	7.2	7	6.5	5.5
Soda Ash	Million ton	14.67	23	24.5	23.5	22
Casutic	Million ton	12.64	24	25	25	24
Paper	Million ton	62.05	110	115	120	120
Fertilize	Million ton	52.2	61	61	61	61
Aluminum	Million ton	7.56	34	36	36	33
Paper	Million ton	46.3	50	50	50	45
Calcium c	Million ton	8.5	10	8	7	4

Population 人口

	2005	2010	2020	2030	2040	2050
Population	1307.56	1360.00	1440.00	1470.00	1470.00	1440.00
Urbanization rate	43%	49%	63%	70%	74%	79%
Urban Population	562.12	666.40	907.20	1029.00	1087.80	1137.60
Person per Household	2.96	2.88	2.80	2.75	2.70	2.65
Urban Household	189.91	221.94	288.00	336.76	364.78	380.38
Rural Population	745.44	693.60	532.80	441.00	382.20	302.40
Person per Household	4.08	3.80	3.50	3.40	3.20	3.00
Rural Household	182.71	189.68	181.03	159.97	151.59	144.00

Parameter of Urban Household: by 2030 same life quality as that in developed countries
城镇居民家庭参数：至2030年生活质量与发达国家水平一致

Service	Unit	Service		
		2020	2030	2050
Household, million		288	336	380
Share of HH with space heating		42%	44%	48%
Index of space heating intensity, 2000=1		1.35	1.5	1.6
Index of space heating time, 2000=1		1.33	1.36	1.4
Share of building with 50% efficiency standard		20%	45%	65%
Ownership of Air Conditioner		130	180	260
Index of Air conditioner intensity, 2000=1		1.3	1.4	1.6
Index of air conditioner utilization time, 2000=1		1.6	1.8	2.2
Ownership of Refrigerator	per 100HH	100	120	130
Average space of refregeretor	L	250	310	390
Efficiency of Refregeretor		0.8kWh/天	0.8kWh/天	0.7kWh/天
Ownership of washing machine	per 100HH	100	100	100
times to use washing machine per week		5.4	8	8
Ownership of TV	per 100HH	180	220	290
Average Capacity of TV		320W	300W	280
Hours per TV per day		3.5	3.2	2.9
Penetration rate of CFL		100%	100%	100%
Light per HH		14	21	27
Ownership of Water heater	per 100HH	100%	100%	100%
Ownership of Solar heater	per 100HH	18%	25%	33%
Ownership of Electric cooking	per 100HH	130	140	260
Hours per day of electric cooking	Minutes	12	30	50
Capacity of other electric applicance	W	1500W	1800W	2300W
Hours of other electric appliance	Minutes	50	80	100

2050年的低碳住宅
舒适和节能

太阳能利用

光伏电池

(25-47% 的家庭拥有屋顶光伏电池，转换效率接近30%

生态生活教育

减少10-20% 能源需求

屋顶植被

太阳热利用

普及率: 20-60%
（目前 6%）

高效照明
【如 LED照明】

减少50%照明需求，
普及率 100%

能源检测系统
（家用电器)

高效绝热

减少 60% 采暖需求，
普及率70%

超高效空调

COP =8，
普及率 100%

燃料电池

普及率 0-20%

热泵采暖

COP＝5
普及率 30-70%

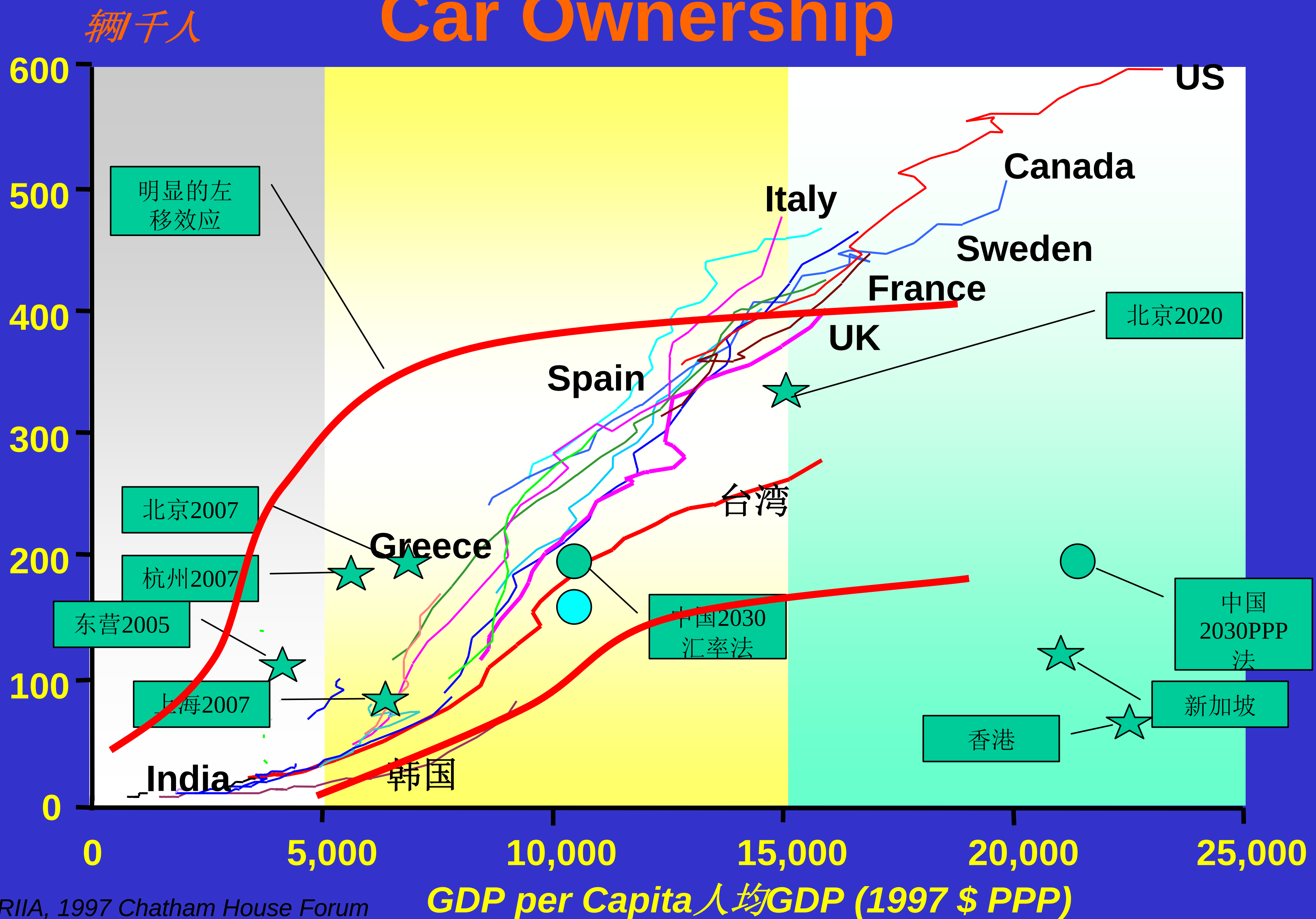
待机电源耗电

降低1/3，
普及率100%

向公众提供经济和环境信息促使大家成为低碳消费

高效家用电器
减少能源需求，支持舒适和安全生活方式

机动车普及率
Car Ownership



Source: RIIA, 1997 Chatham House Forum

Vehicle fleet, Low Carbon scenario, 10000
车队，低碳情景，10000

	2000	2005	2010	2020	2030	2040	2050
Total Vehicle	1609	3160	6227	18583	36318	51717	55810
Passenger	854	2132	4299	15504	32323	46083	48922
Freight	716	1027	1928	3079	3995	5634	6888
Car	670	1919	3921	14982	31558	45075	47662
Family Car	57	1100	3145	14032	30454	43675	46062
Other Car	613	819	776	950	1104	1400	1600
Mini-Bus	108	131	265	313	383	524	214
Large Bus	75.3293	82.3080335	113.4	208.8	382.5	483.84	1045.8
Bus	184	214	378	522	765	1008	1260
Motor Cycle	3771	6582	9848	10613	11193	11193	10634

Transport, Low carbon scenario
交通，低碳情景

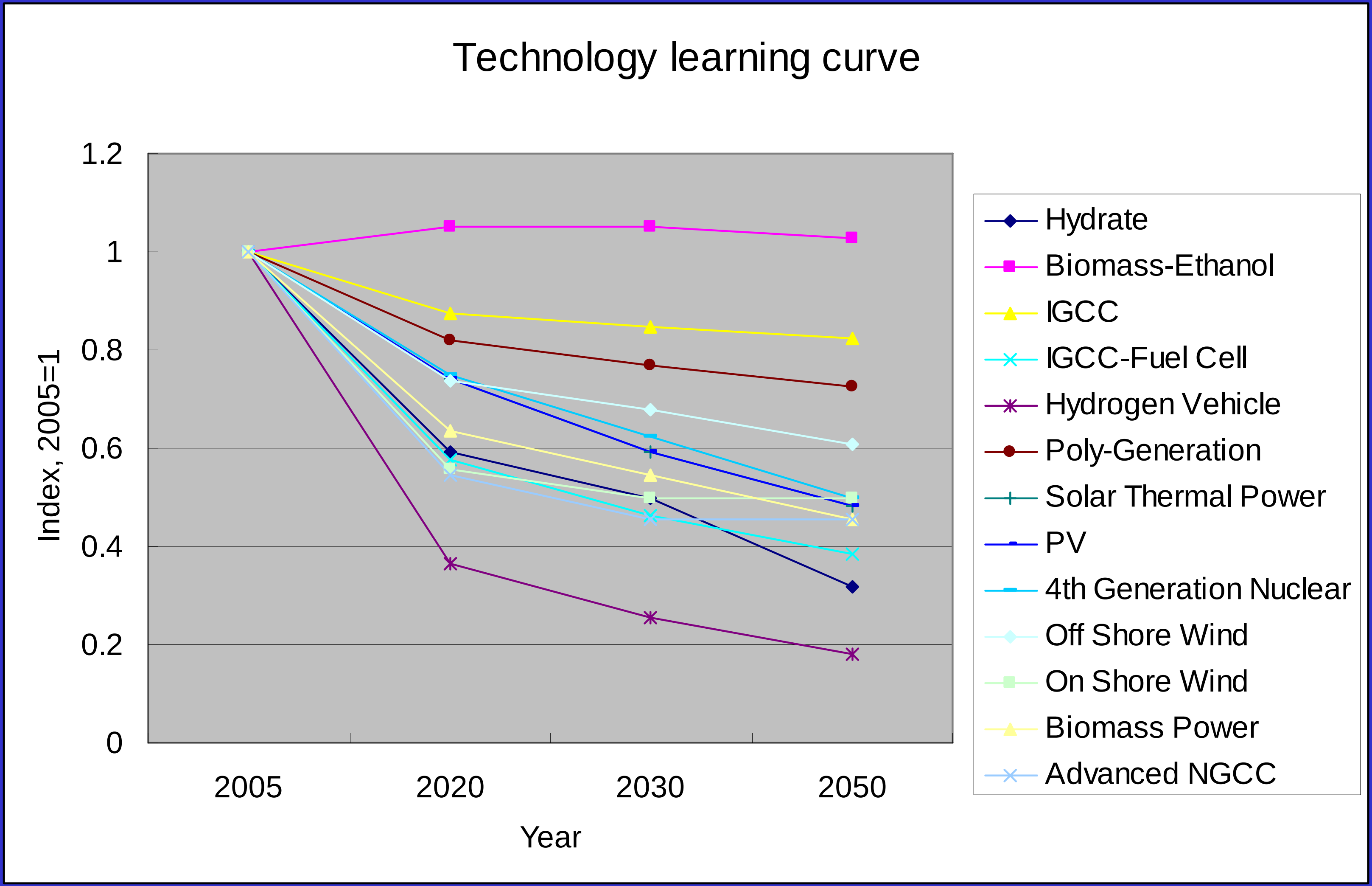
		2005	2010	2020	2030	2040	2050
Family car ownership, per 100HH	Urban	3.37	14	36	65	77	78
	Rural	0.08	0.2	8	38	70	90
Family car annual travel distance, km		9500	9500	9300	8635	8300	7480
Average engin size of family cars, litter		1.7	1.6	1.6	1.6	1.5	1.4
Fuel efficiency of car, L/100km		9.2	8.9	7.1	5.9	4.8	4.1
Share of MRT in total traffic volume, %		0.011	0.016	0.025	0.046	0.1	0.21
Share of Biofuel, %		1.10%	1.30%	4.1%	7.70%	12%	13%
Share of electric car, %		0%	0.12%	3.2%	6.80%	12.5%	19.8%
Share of fuel cell car, %		0%	0%	0.80%	1.60%	4.70%	7.90%

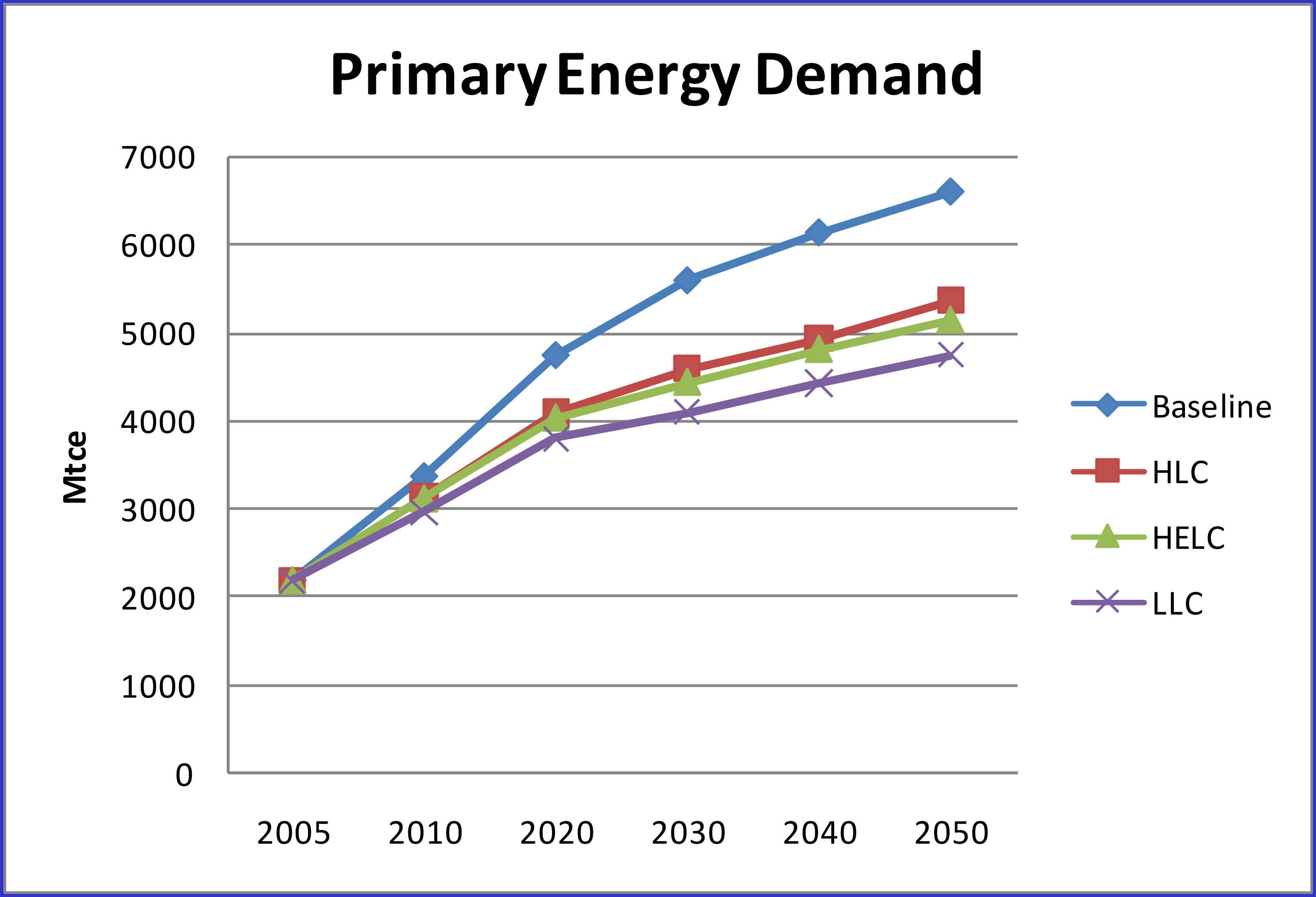
Comparison of BaU and Low Carbon Scenario
基准线情景与低碳情景的对比

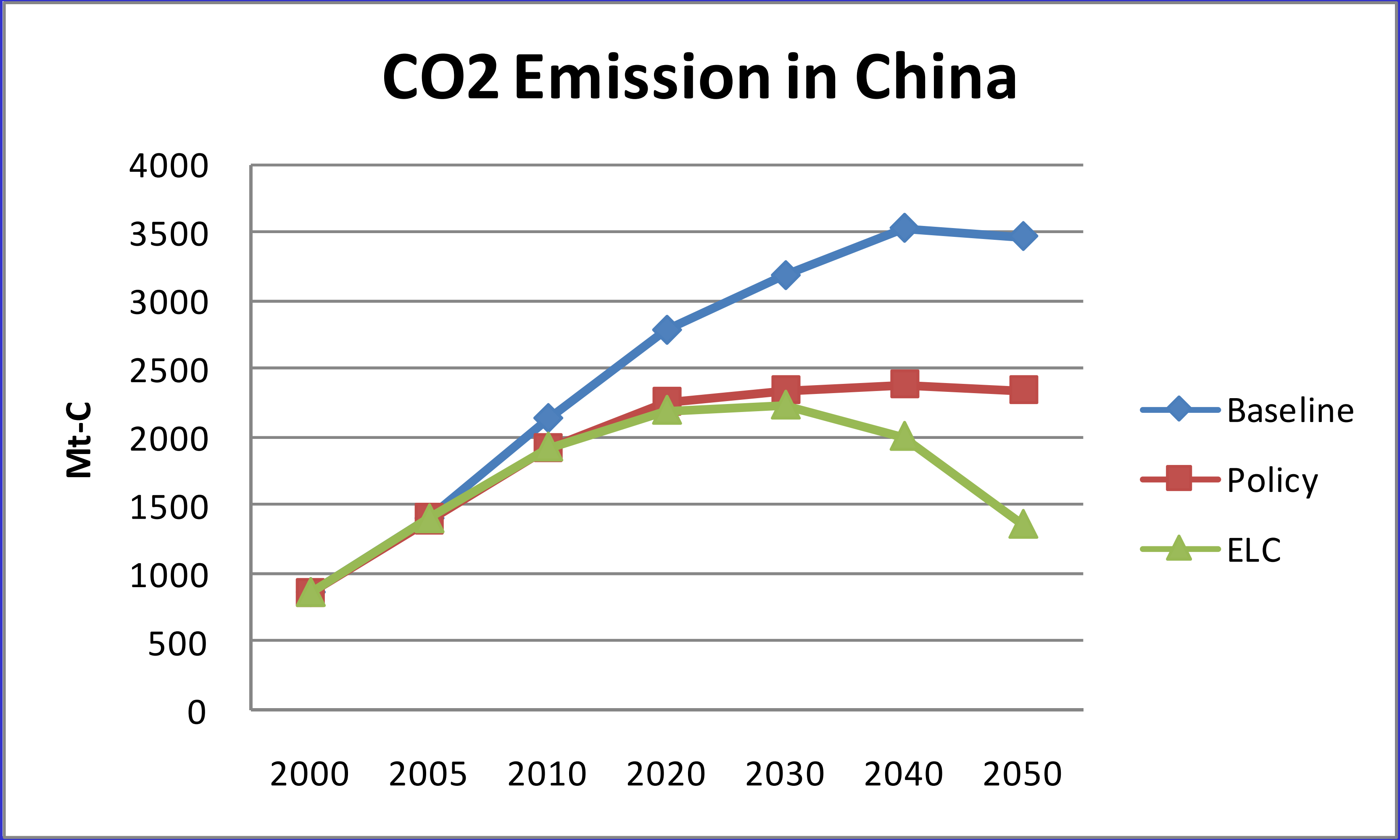
nology	Efficiency	Ratio in 2030		Ratio in 2050		Note
		Reference scenario	Low carbon scenario	Reference scenario	Low carbon Scenario	
ed coke	11900 Mcal/ ton coke, with gas production of 1340 Mcal	58%	50%	77%	42%	Fully localization
generation en	10300 Mcal/ ton coke, with gas production of 1420Mcal	17%	47%	23%	58%	
nching	2.4 Mcal/ ton J Recovery	80%	100%	90%	100%	Localization, with promising prospect of market potential
g furnace ternational d level	390 Mcal/ ton sinter lump, saving 42% of energy	45%	85%	67%	90%	Needed to be localization
urnace of onal d level	3750 Mcal/ ton hot metal, saving 21% of energy	40%	65%	64%	87%	
s recovery	Heat and electricity recovery 0.7 Mcal/ ton hot metal	44%	70%	85%	100%	
ous and	Saving 86% of energy	90%	98%	85%	95%	

Unit energy use for key products, LCS Scenario
主要产品的单位能源使用，LCS情景

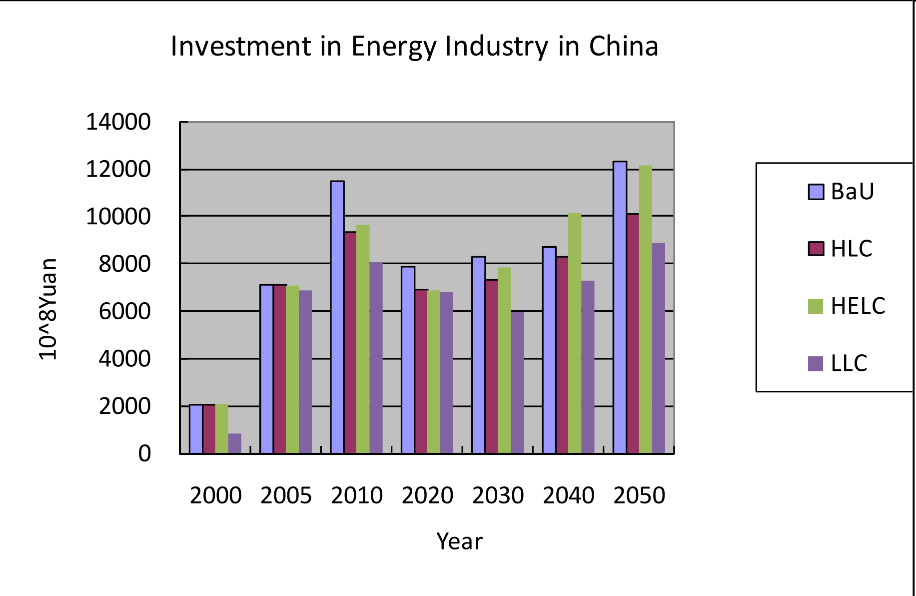
	Unit	2005	2020	2030	2040	2050
Steel	Kgce/t	760	650	564	554	545
Cement	Kgce/t	132	101	86	81	77
Glass	Kgce/Weight Cases	24	18	14.5	13.8	13.1
Brick	Kgce/万块	685	466	433	421	408
Ammonia	Kgce/t	1645	1328	1189	1141	1096
Ethylene	Kgce/t	1092	796	713	693	672
Soda Ash	Kgce/t	340	310	290	284	279
Casutic	Kgce/t	1410	990	890	868	851
Calcium carbide	Kgce/t	1482	1304	1215	1201	1193
Copper	Kgce/t	1273	1063	931	877	827
Aluminum	kWh/t	14320	12870	12170	11923	11877
Paper	Kgce/t	1047	840	761	721	686
Electricity fossil fuel	Gce/kWh	350	305	287	274	264

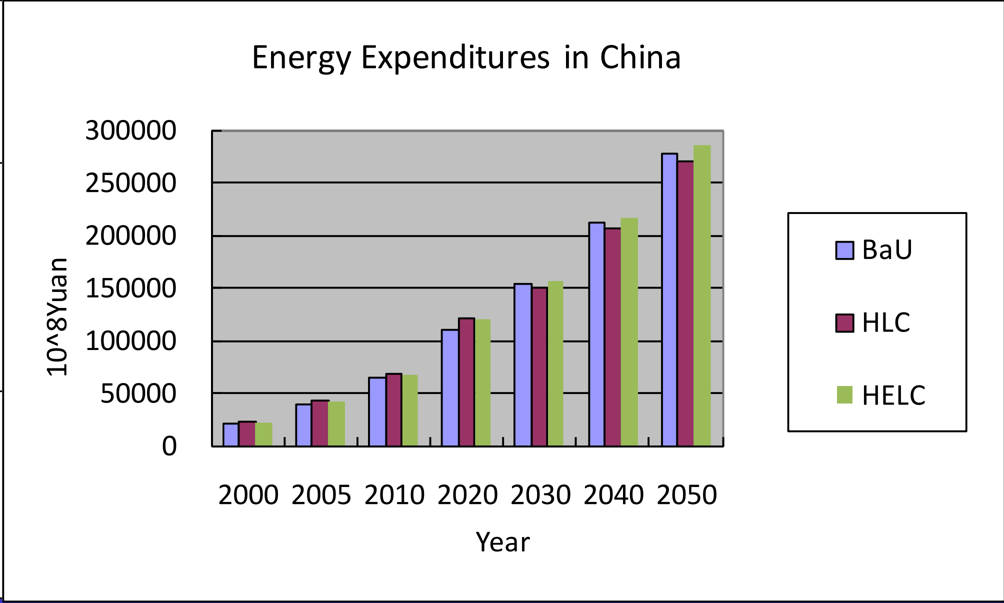

Technology learning curve
1.2
1
0.8
0.6
0.4
0.2
0
Index, 2005=1
2005
2020
2030
2050
Year
Hydrate
Biomass-Ethanol
IGCC
IGCC-Fuel Cell
Hydrogen Vehicle
Poly-Generation
Solar Thermal Power
PV
4th Generation Nuclear
Off Shore Wind
On Shore Wind
Biomass Power
Advanced NGCC

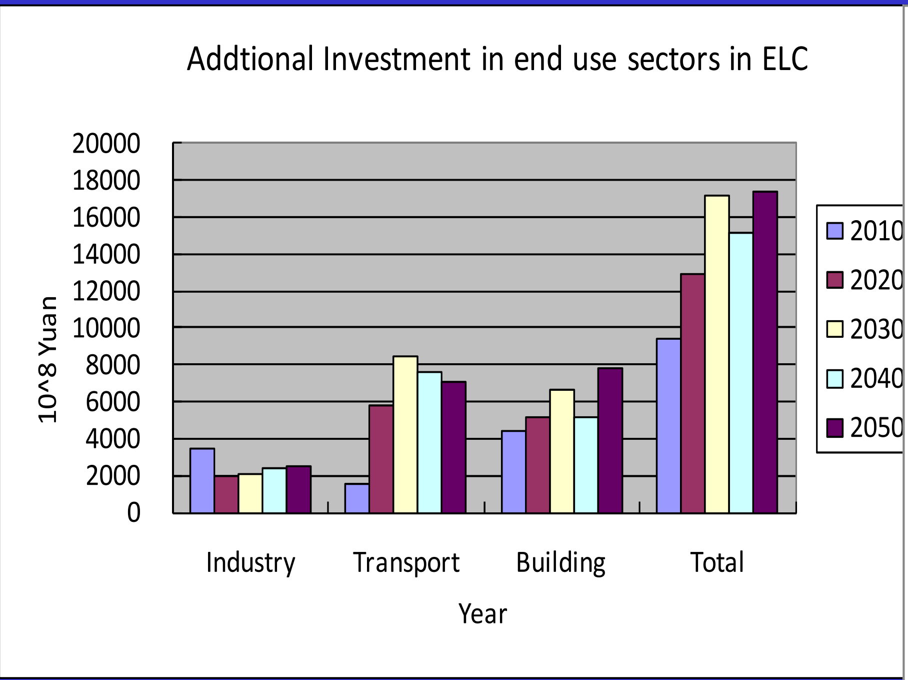

Primary Energy Demand
Mtce
7000
6000
5000
4000
3000
2000
1000
0
2005
2010
2020
2030
2040
2050
Baseline
HLC
HELC
LLC

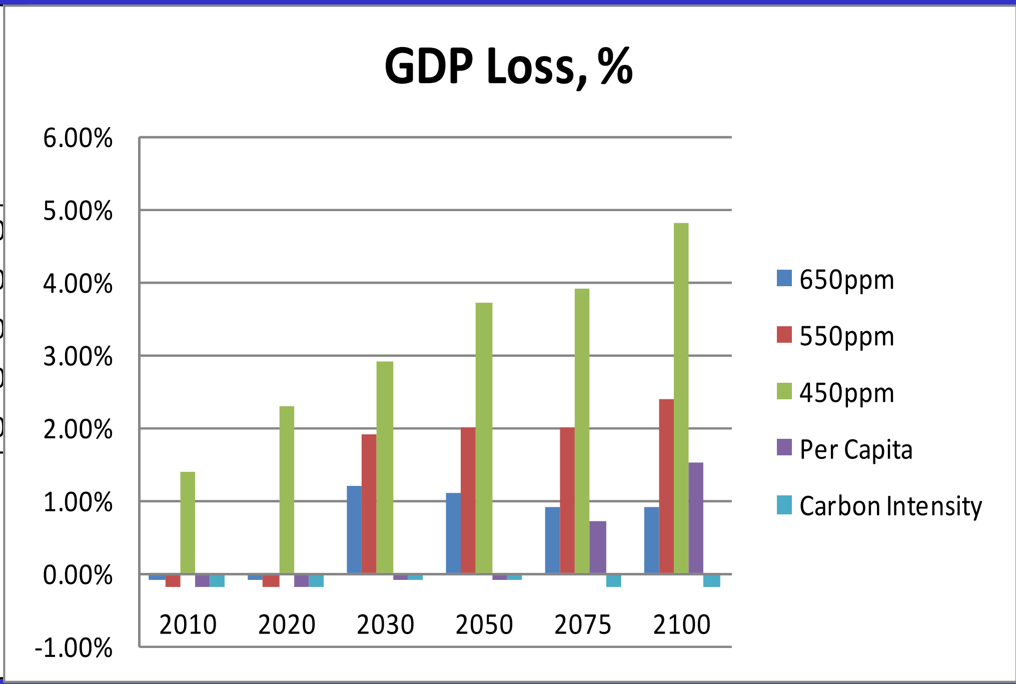


CO2 Emission in China
Mt-C
4000
3500
3000
2500
2000
1500
1000
500
0
2000
2005
2010
2020
2030
2040
2050
Baseline
Policy
ELC

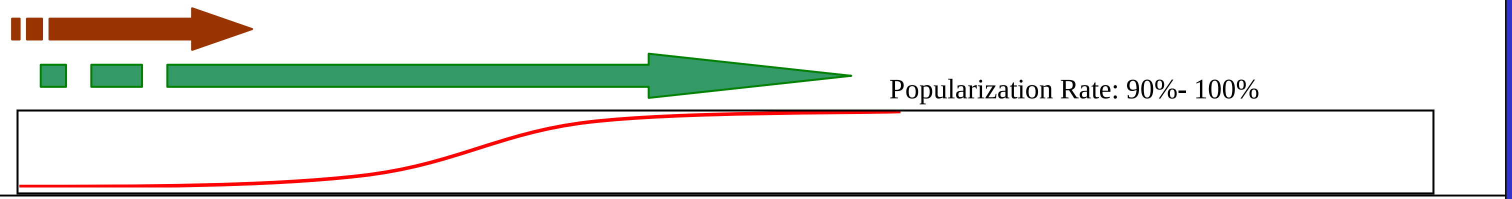
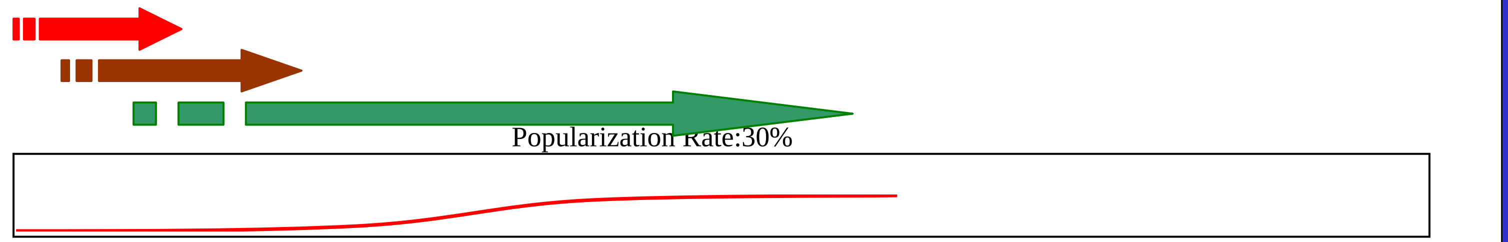

Investment in Energy Industry in China
14000
12000
10000
8000
6000
4000
2000
0
10^8Yuan
2000 2005 2010 2020 2030 2040 2050
Year
BaU
HLC
HELC
LLC


Energy Expenditures in China
300000
250000
200000
150000
100000
50000
0
10^8Yuan
2000 2005 2010 2020 2030 2040 2050
Year
BaU
HLC
HELC

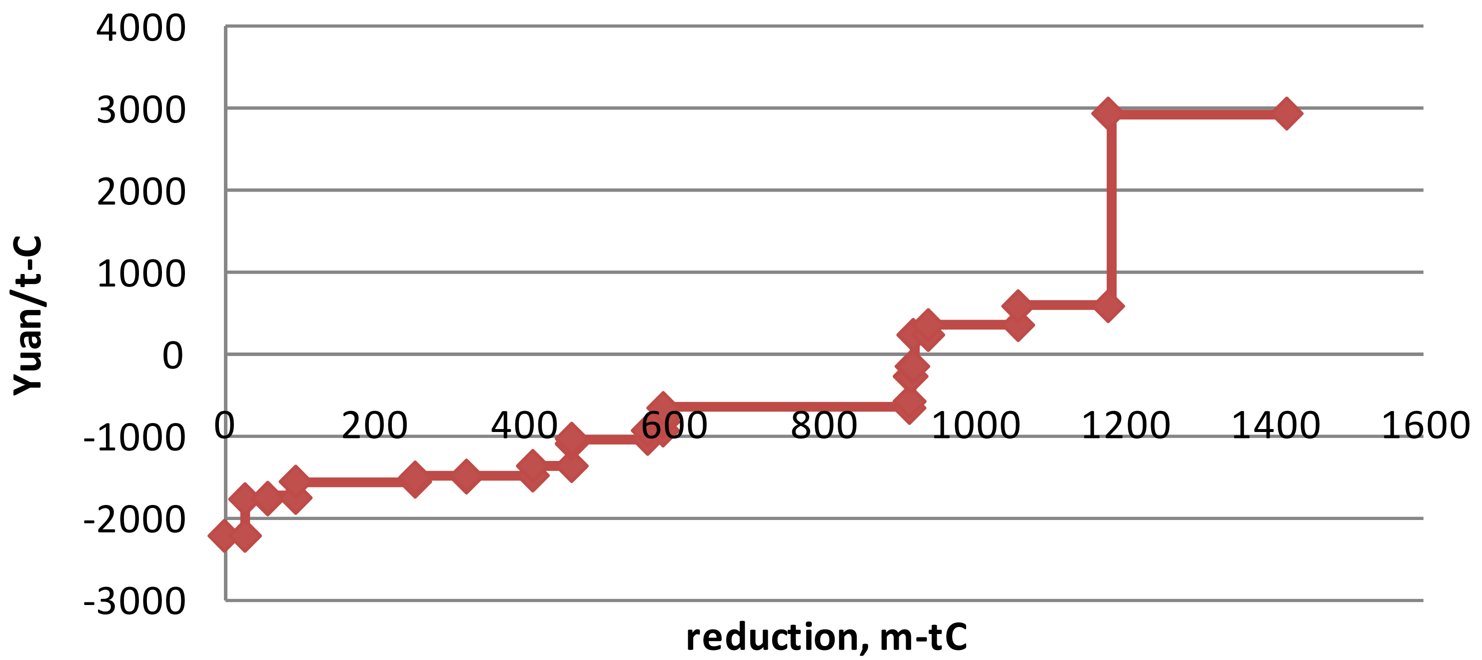

Addtional Investment in end use sectors in ELC
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
10^8 Yuan
Industry
Transport
Building
Total
Year
2010
2020
2030
2040
2050

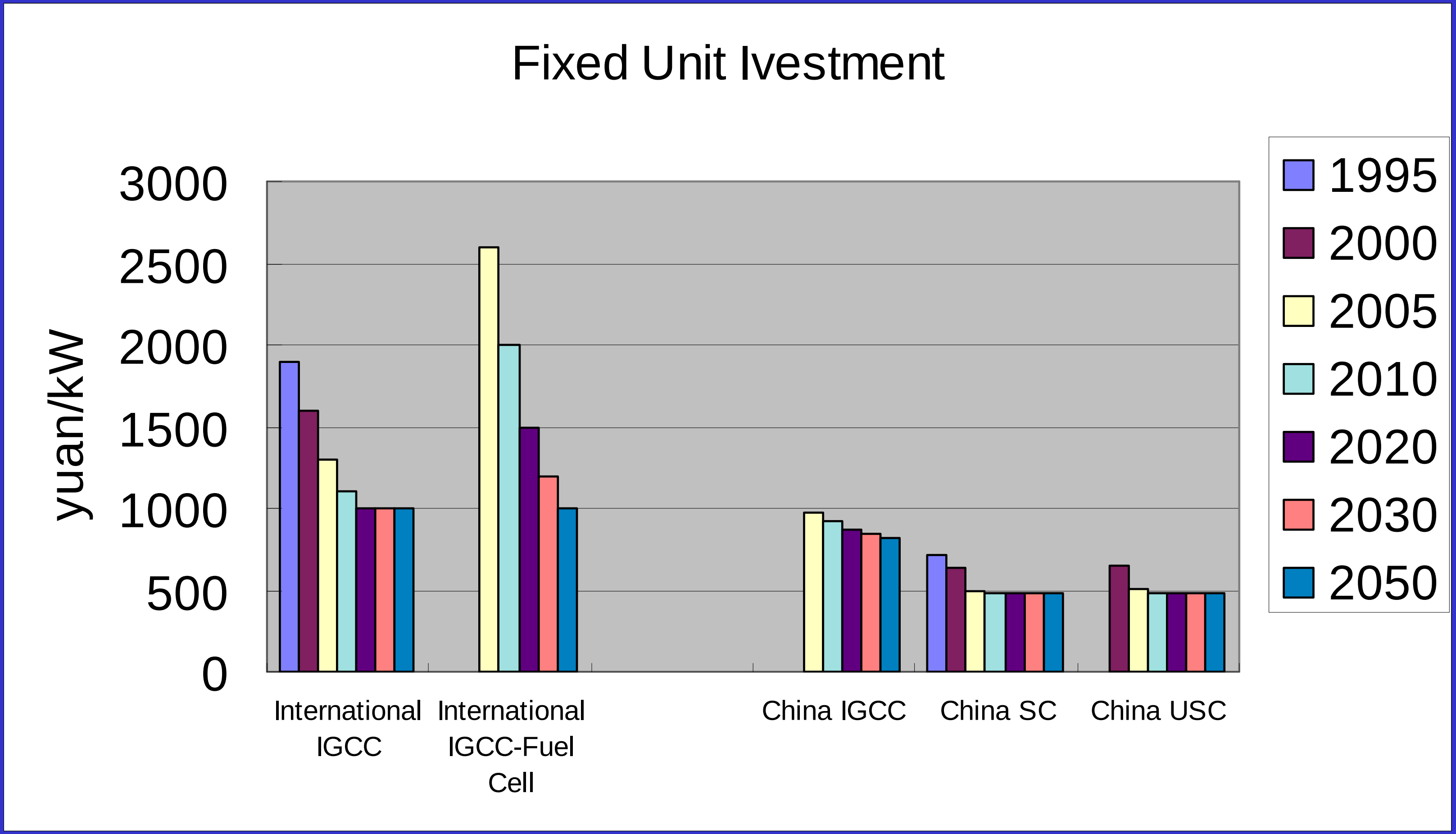

GDP Loss, %
6.00%
5.00%
4.00%
3.00%
2.00%
1.00%
0.00%
-1.00%
2010 2020 2030 2050 2075 2100
650ppm
550ppm
450ppm
Per Capita
Carbon Intensity

Technology Roadmap 技术路线图

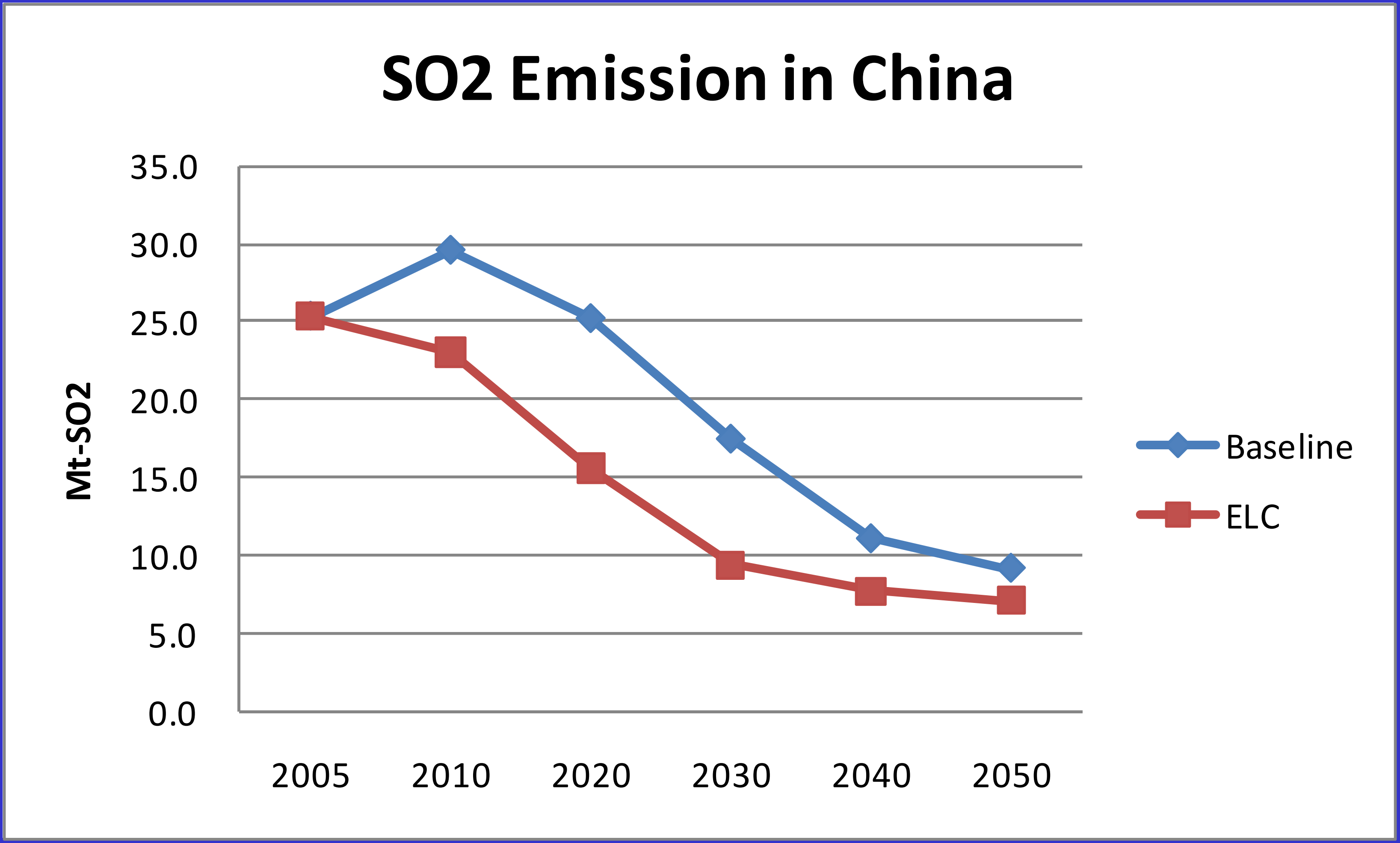
Field	Technology	2010	2015	2020	2025	2030	2035	2040	2045	2050
Industry	Advanced energy technique of industry									
Transport	Hybrid Electric Vehicle									

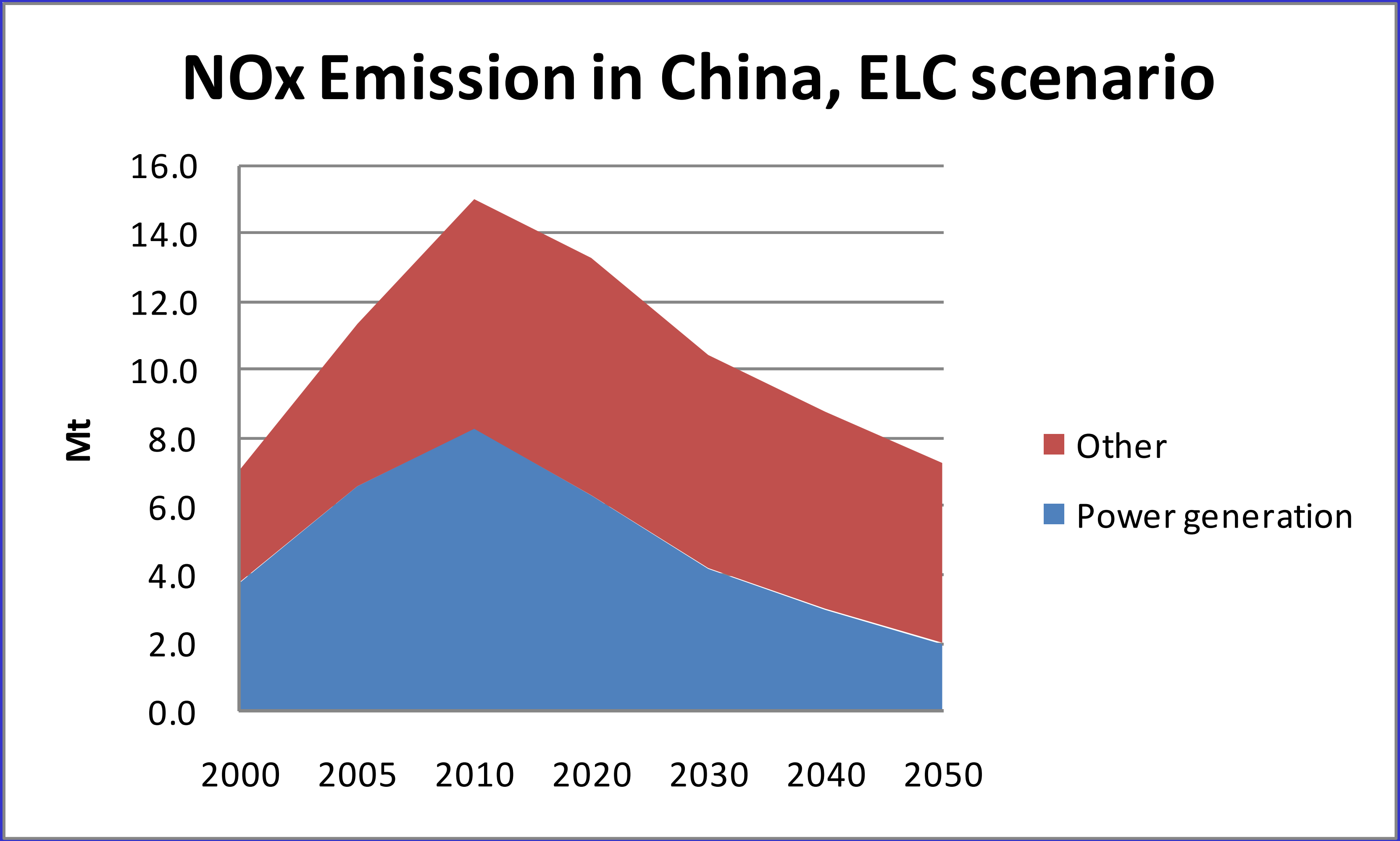
Cost curve in power generation in China, 2050



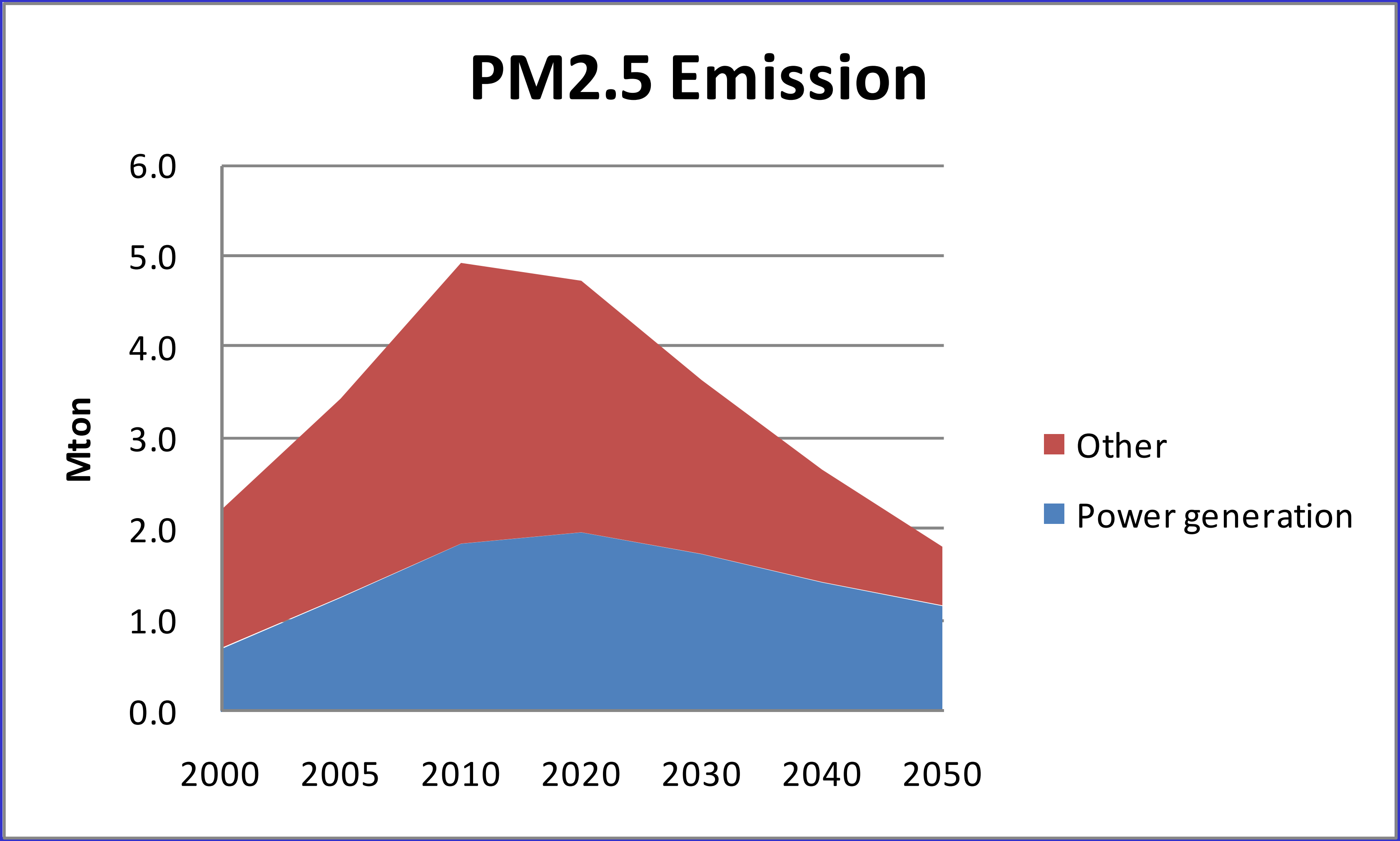


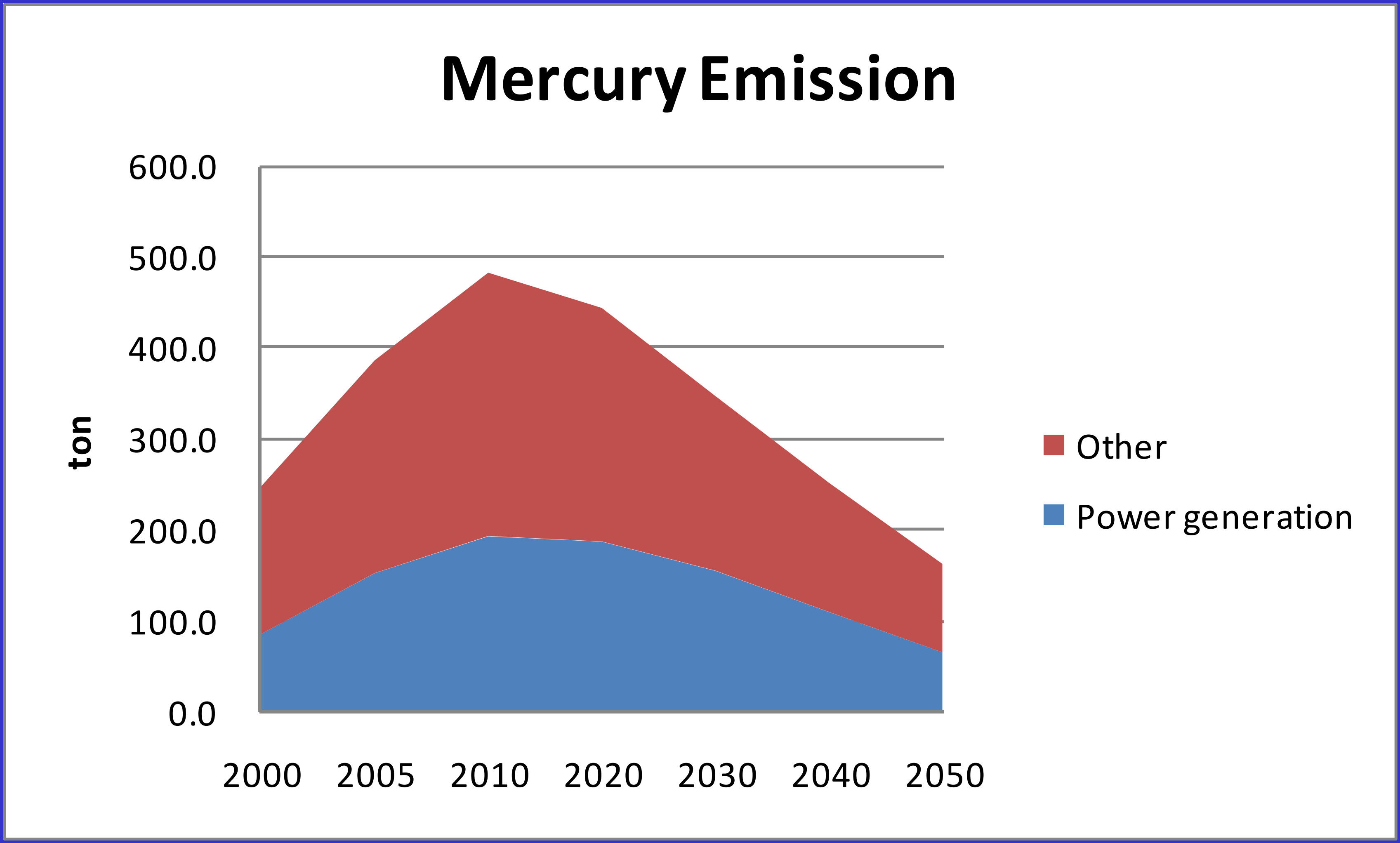
Fixed Unit Ivestment
yuan/kW
3000
2500
2000
1500
1000
500
0
International IGCC
International IGCC-Fuel Cell
China IGCC
China SC
China USC
1995
2000
2005
2010
2020
2030
2050


SO2 Emission in China
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Mt-SO2
2005
2010
2020
2030
2040
2050
Baseline
ELC

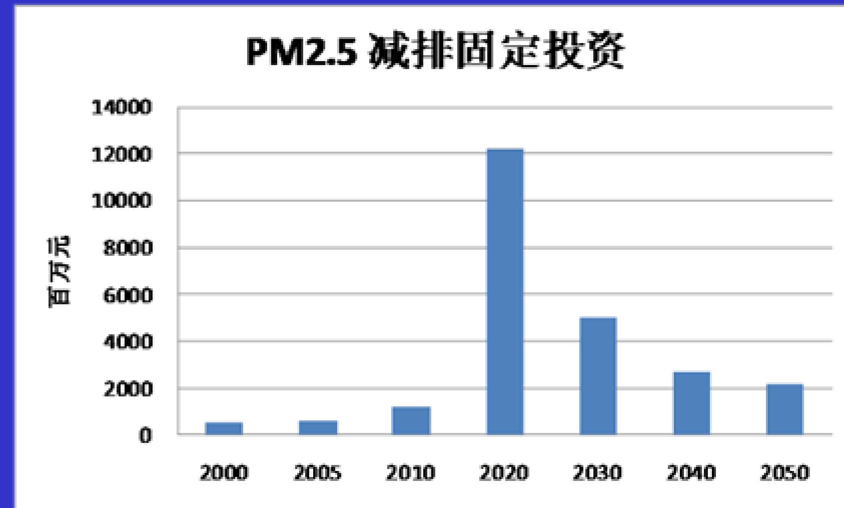


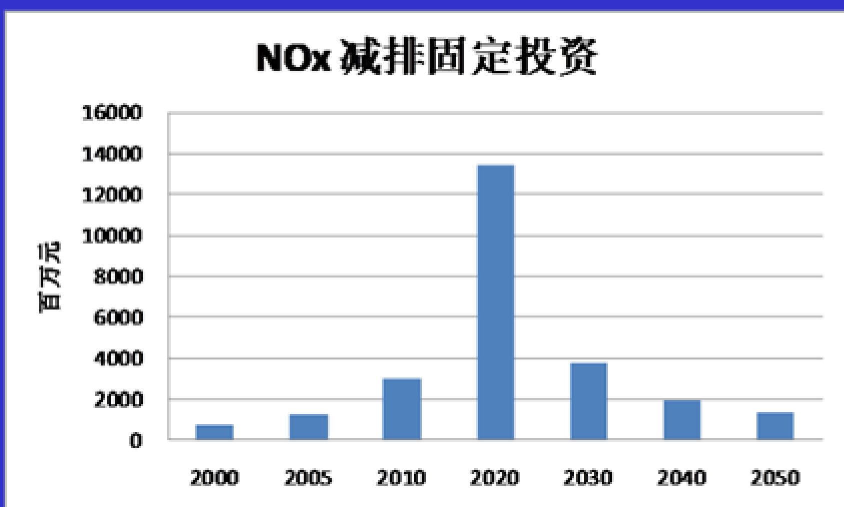
NOx Emission in China, ELC scenario
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Mt
2000
2005
2010
2020
2030
2040
2050
Other
Power generation

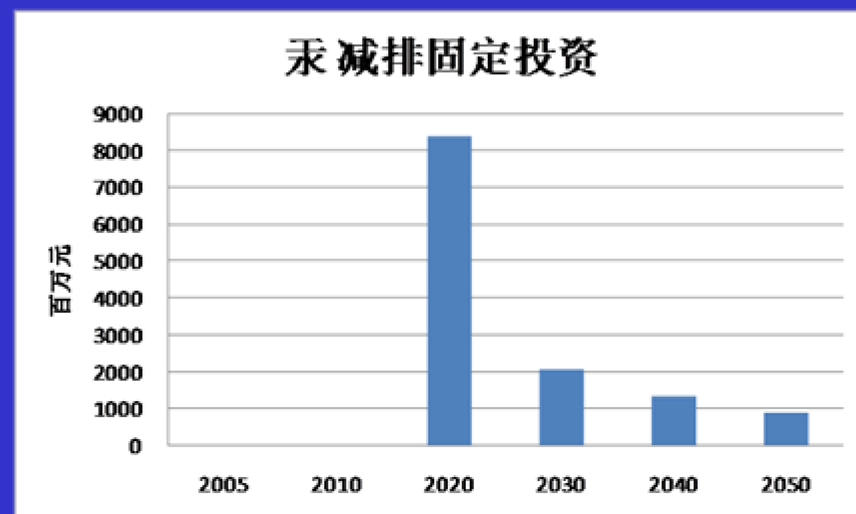

PM2.5 Emission
Mton
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2000
2005
2010
2020
2030
2040
2050
Other
Power generation


Mercury Emission
600.0
500.0
400.0
300.0
200.0
100.0
0.0
ton
2000
2005
2010
2020
2030
2040
2050
Other
Power generation

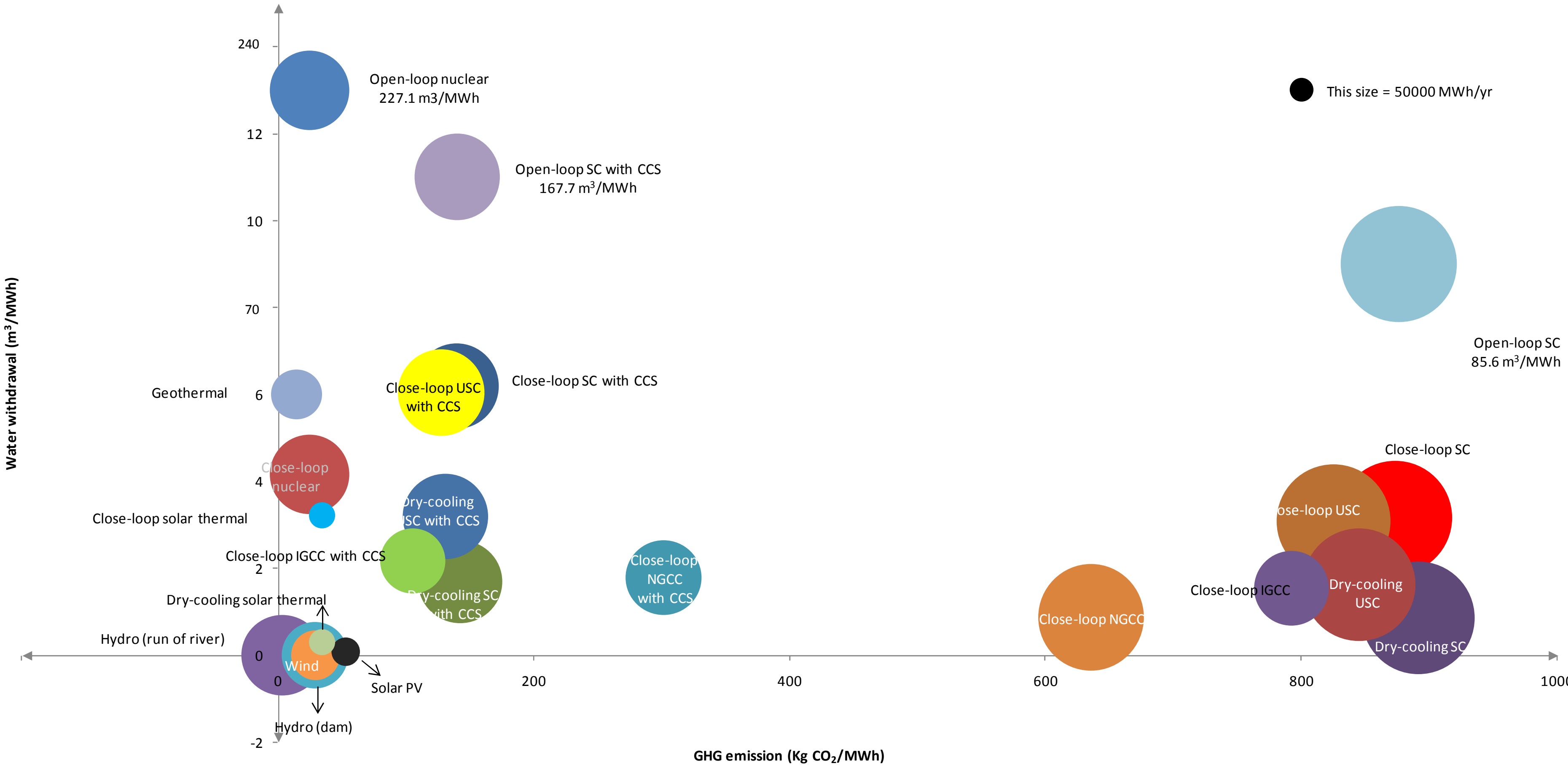

SO2减排固定投资
12000.0
10000.0
8000.0
6000.0
4000.0
2000.0
0.0
百万元
2000
2005
2010
2020
2030
2040
2050


PM2.5 减排固定投资
14000
12000
10000
8000
6000
4000
2000
0
百万元
2000
2005
2010
2020
2030
2040
2050

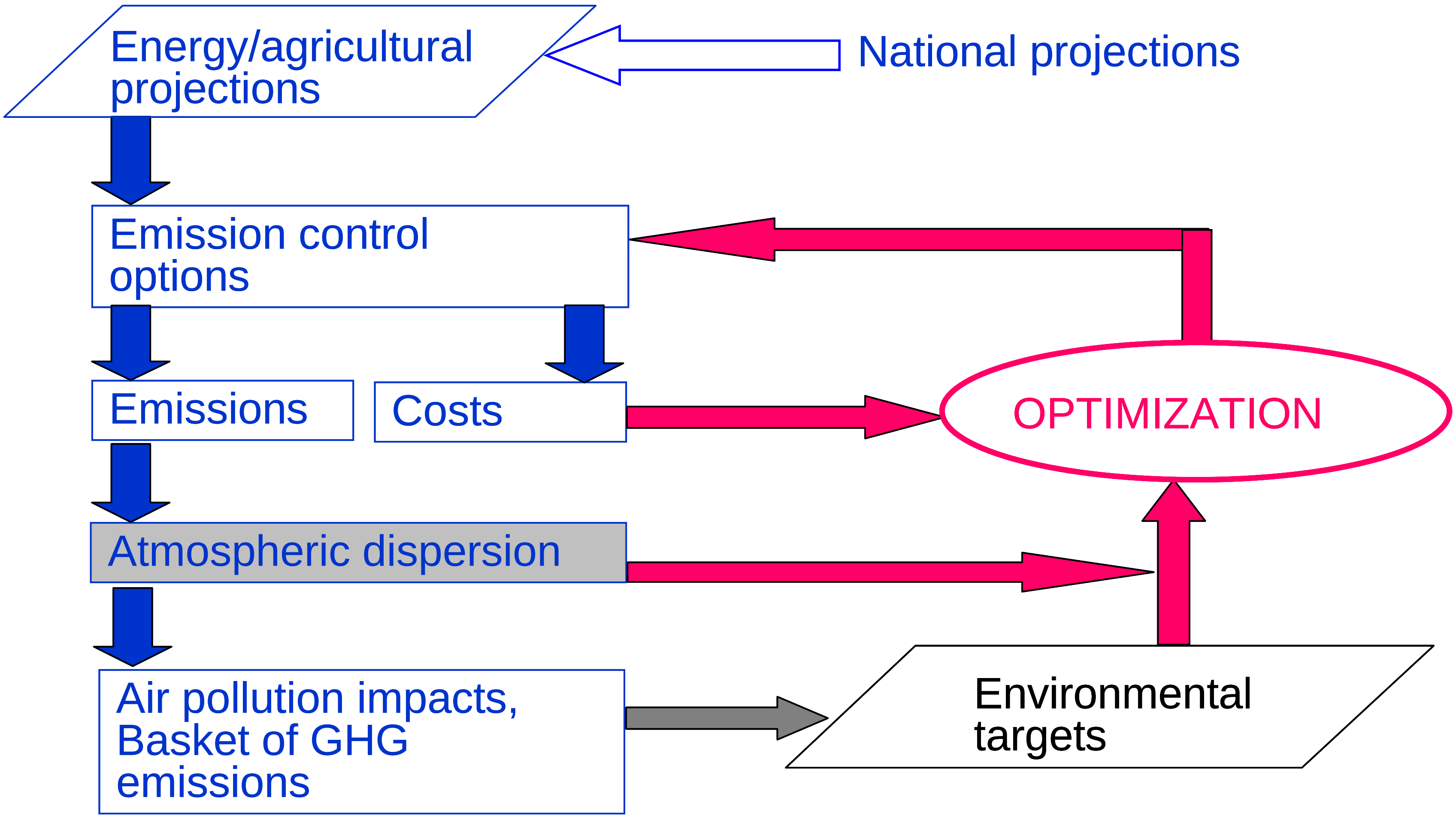

NOx 减排固定投资
16000
14000
12000
10000
8000
6000
4000
2000
0
百万元
2000
2005
2010
2020
2030
2040
2050


汞 减排固定投资
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
百万元
2005
2010
2020
2030
2040
2050

发电设备用水需求和温室气体排放



The GAINS model follows pollution from its sources to their impacts
GAINS模型：从污染源到其影响

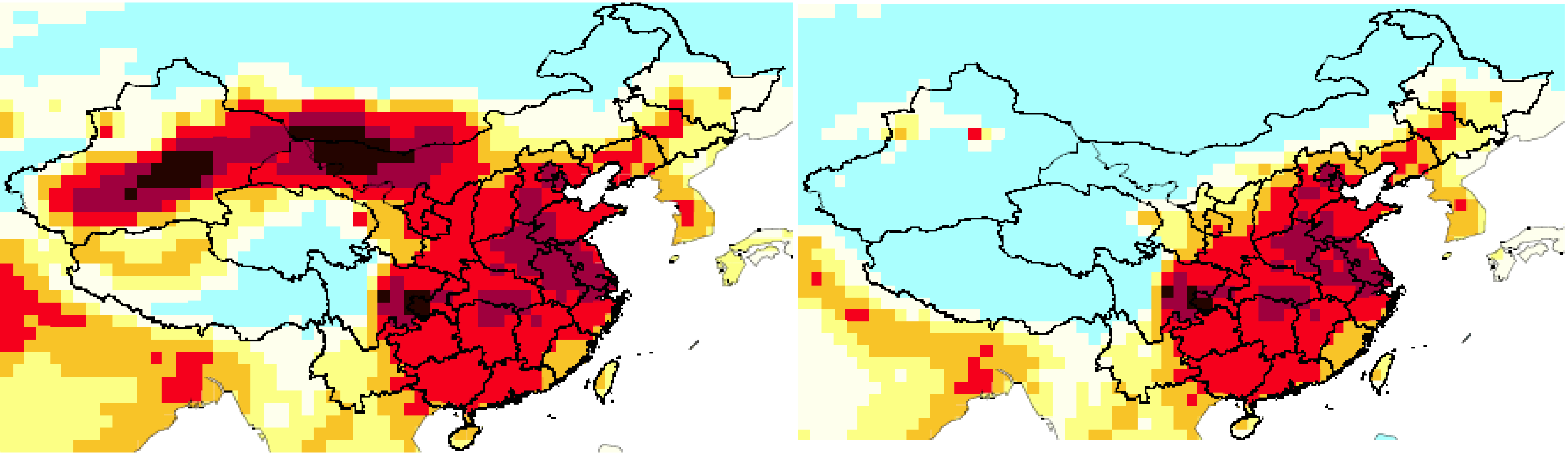


Air pollution emissions by province for 2005 and 2030, for the Current legislation (CLE) baseline projection, the case with across-the-board application of advanced control technologies for large sources (ACT) and the cost-effective allocation determined with the GAINS model (OPT), in kilotons

2005年与2030年各省空气污染排放。目前的立法（CLE）基线预测，大排放源的高级控制技术（ACT）的全面应用，与由GAINS模型（OPT）决定成本效益配置，以千吨计。

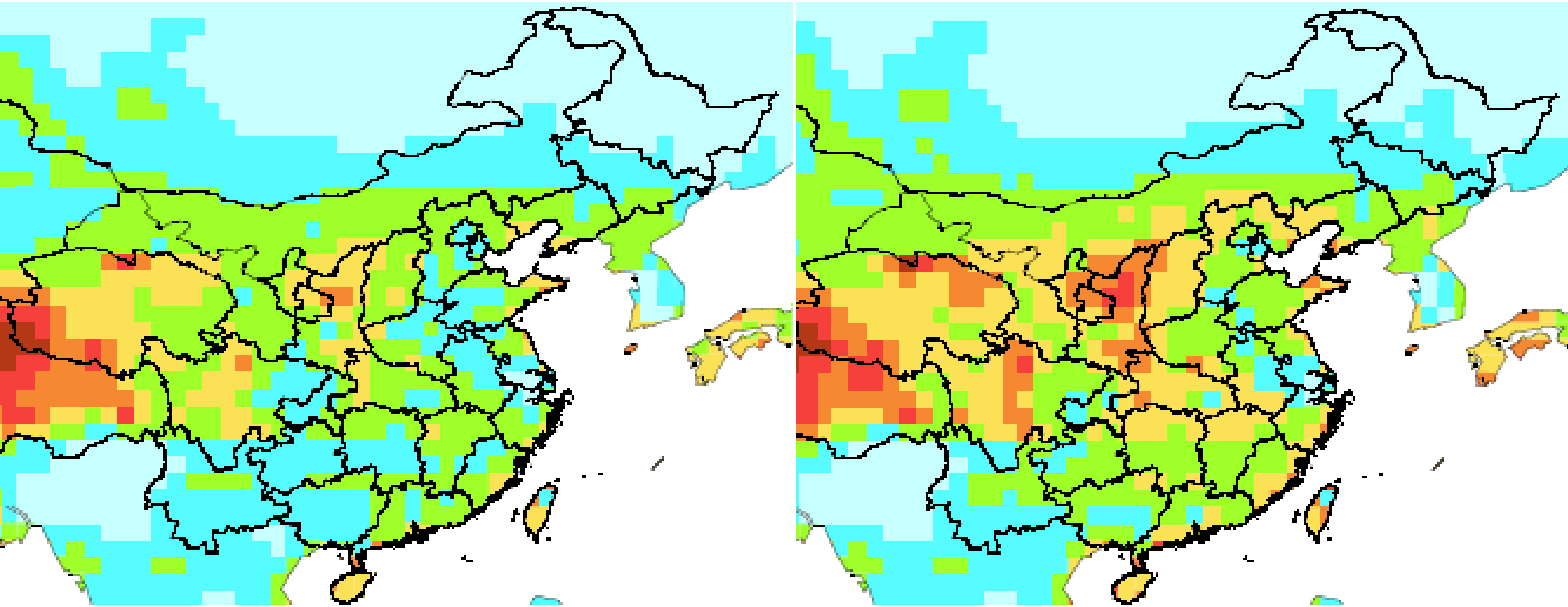
	SO_2				NO_x				PM2.5			
	2005	CLE	ACT	OPT	2005	CLE	ACT	OPT	2005	CLE	ACT	OPT
ANHUI	1143	1095	556	607	753	1064	459	534	614	498	263	162
BEIJING	450	394	248	314	285	323	152	238	115	111	67	35
CHONGQING	928	1474	973	578	308	508	220	275	217	191	79	61
FUJIAN	458	409	176	243	323	410	181	298	175	155	52	61
GANSU	371	309	141	205	279	347	158	195	214	168	74	76
GUANGDONG	1706	1431	441	730	1022	1280	543	978	638	486	189	195
GUANGXI	737	877	422	370	312	428	193	312	397	281	139	165
GUIZHOU	758	881	514	340	285	396	172	259	234	215	105	93
HAINAN	62	42	19	29	64	70	41	56	107	58	46	29
HEBEI	2211	2108	1059	1279	1170	1613	728	1258	941	827	315	217
HEILONGJIANG	460	538	213	509	555	886	364	814	404	339	185	229
HENAN	1638	1504	601	696	876	1182	488	553	815	713	224	159
HONGKONG	21	16	10	12	213	205	111	201	17	15	10	14
HUBEI	1288	1386	705	666	688	1000	435	503	597	472	213	152
HUNAN	745	693	336	389	425	501	235	261	452	391	177	174
I. MONGOLIA	518	533	246	397	375	645	264	568	355	303	152	96
JIANGSU	2179	1844	768	1048	1220	1798	731	817	1007	881	323	214
JIANGXI	536	493	222	293	316	410	184	198	329	294	122	119
JILIN	1830	1695	869	1291	943	1395	630	1224	574	523	238	146
LIAONING	1221	1302	596	845	559	1007	388	441	321	346	120	216
NINGXIA	316	296	108	131	115	212	76	79	76	86	27	27
QINGHAI	74	103	43	61	71	120	48	86	53	64	19	23
SHAANXI	912	954	427	440	337	510	206	231	270	281	113	77
SHANDONG	1337	1520	625	814	815	1362	658	1362	212	284	97	92
SHANGHAI	2791	2506	993	1339	1393	2026	908	971	1137	917	332	229
SHANXI	1927	1839	952	1016	709	1087	445	501	470	499	123	104
SICHUAN	1773	2019	1284	806	566	726	357	415	854	571	337	225
TIANJIN	537	620	315	420	568	873	481	763	120	123	57	42
TIBET XIZANG	4	39	10	39	9	75	24	73	14	28	11	28
XINJIANG	397	463	205	271	240	364	149	291	157	144	61	94
YUNNAN	447	465	216	278	300	399	181	345	319	262	109	139
ZHEJIANG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Computed annual mean PM2.5 concentrations in China for the baseline projection in 2030; left panel: including natural sources and soil dust, right panel: from anthropogenic sources only (used for health impact calculation)



2030年中国年均PM2.5浓度基线预测；
左图：包括自然资源与扬尘
右图：人为来源（用于健康影响计算）

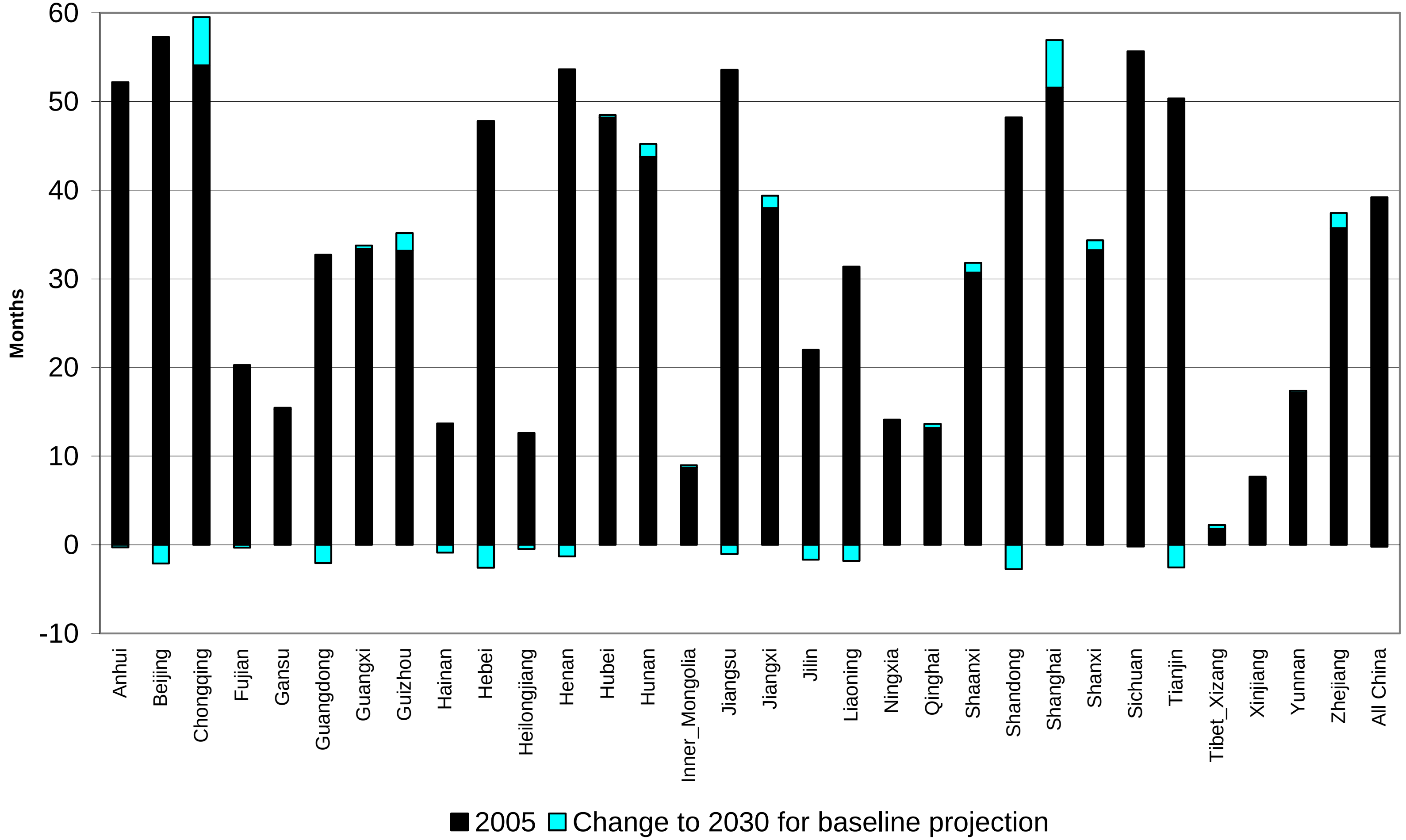
Computed health-relevant ozone concentrations for China (SOMO35, i.e., Sum of daily 8-hour mean concentrations exceeding 35 ppb) computed for 2005 (left panel) and 2030 (right panel)



中国的健康相关的臭氧浓度（SOMO35，例如，日8小时平均浓度总量超过35ppb），左图为2005年，右图为2030年。

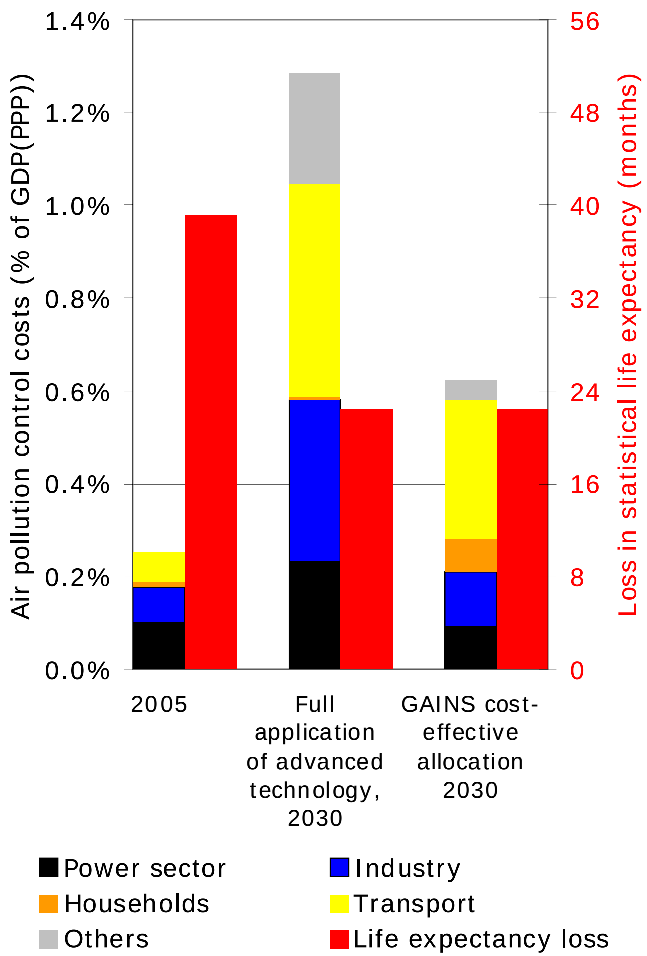
Loss in statistical life expectancy in China attributable to outdoor pollution of PM2.5 in 2005 and the baseline projection for 2030

2005年由于PM2.5户外污染造成的中国统计预期寿命损失与2030年基线预测



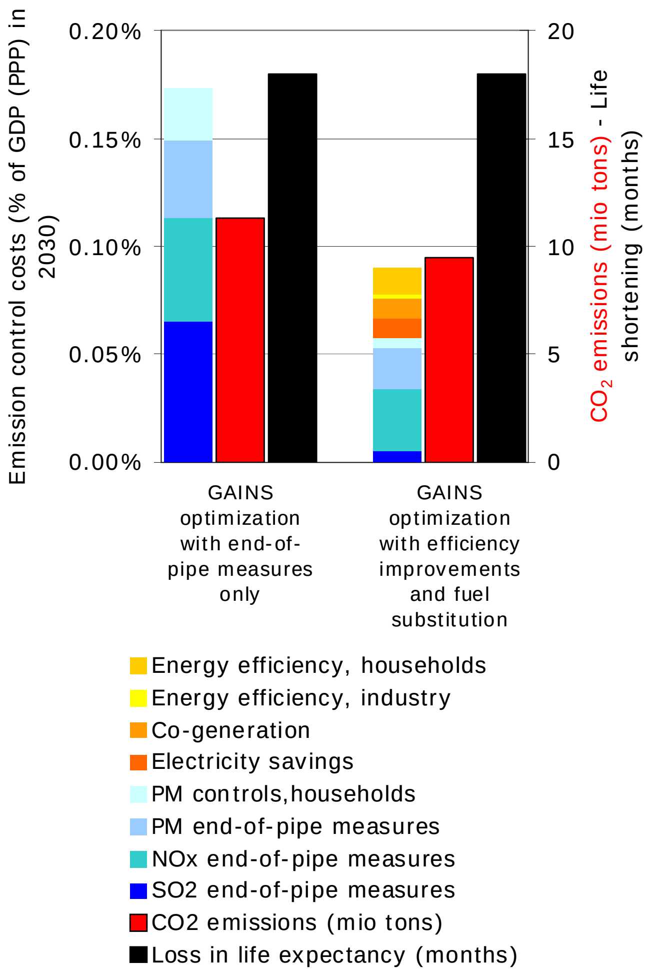
The GAINS cost-effectiveness approach can reduce costs for improving air quality by up to 50%
GAINS成本效益方法，能够减少50%空气改善成本

- Advanced emission control technologies are available to maintain acceptable levels of air quality despite the pressure from growing economic activities.
  尽管经济增长造成压力，先进的排放控制技术还是能够保持空气质量的可接受水平。
- The optimization mode of the GAINS model can identify the most cost-effective portfolio of measures to improve air quality. GAINS模型的优化模式能够辨别最具成本效益的投资组合措施来提高空气质量。



Well-designed air pollution control strategies can also reduce GHG emissions
精心设计的空气污染控制策略也能减少温室气体排放

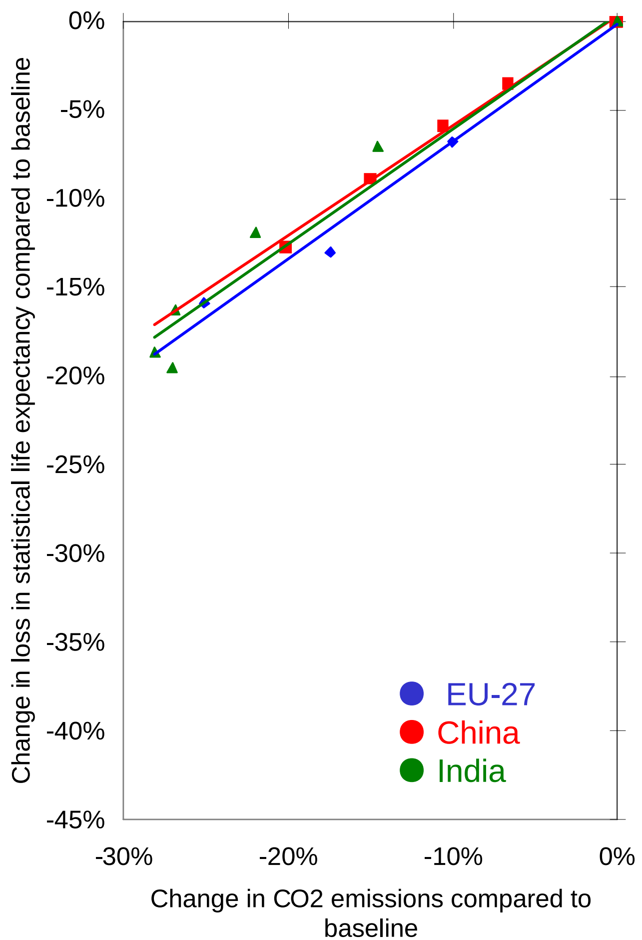
- Measures exist that simultaneously reduce emissions of air pollutants and greenhouse gases. 措施能够同时减少空气污染物与温室气体排放。
- GAINS identifies cost-effective measures that not only improve air quality but also reduce greenhouse gas emissions. GAINS能够辨别提高空气质量且减少温室气体排放的经济有效的措施。
- Such measures also form part of a cost-effective air pollution control strategy. 这些措施也能成为经济有效的空气污染控制策略的一部分。



Low carbon strategies have significant health benefits in Asia and Europe

低碳策略在亚洲和欧洲均有显著的健康收益

- Low CO_2 strategies result in less SO_2, NO_x and PM emissions. 低CO_2策略会导致更少的SO_2，NO_x和颗粒物排放。
- Significant health impacts from air pollution occur as a co-benefit of CO_2 mitigation. CO_2减排的协同效益是减少空气污染所带来的健康改善。
- Lower consumption of coal and oil also reduce air pollution control costs. In Europe, such cost savings can compensate up to 40 percent of CO_2 mitigation costs. 煤与油的低消耗能够减少空气污染控制成本。在欧洲，这样的成本节约能够补偿40%的CO_2减排成本。



Costs of emission control measures for the GAINS optimization with air pollution measures only (left column) and the optimization with structural changes (billion €/yr)

GAINS优化空气污染措施（左栏）与结构变化优化排放控制措施成本（十亿欧元/年）

	GAINS optimization with end-of-pipe air pollution control measures only	GAINS optimization with structural measures
END-OF-PIPE AIR POLLUTION CONTROL MEASURES:		
LARGE PLANTS, SO_2 CONTROLS	13.7	2.8
LARGE PLANTS, NO_x CONTROLS	9.9	6.1
LARGE PLANTS, PM CONTROLS	7.1	5.2
HOUSEHOLDS, PM CONTROL	2.9	0.6
SUB-TOTAL	33.5	14.7
STRUCTURAL MEASURES:		
ELECTRICITY SAVINGS, RENEWABLE ENERGY		0.6
CO-GENERATION OF HEAT AND POWER		2.9
ENERGY EFFICIENCY, INDUSTRY		0.4
ENERGY EFFICIENCY, HOUSEHOLDS		2.2
SUB-TOTAL		6.1
TOTAL	33.5	20.9