Modelling Technology-Oriented Strategic Cooperation on Climate Change Mitigation between the EU, India and China

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ORDECSYS

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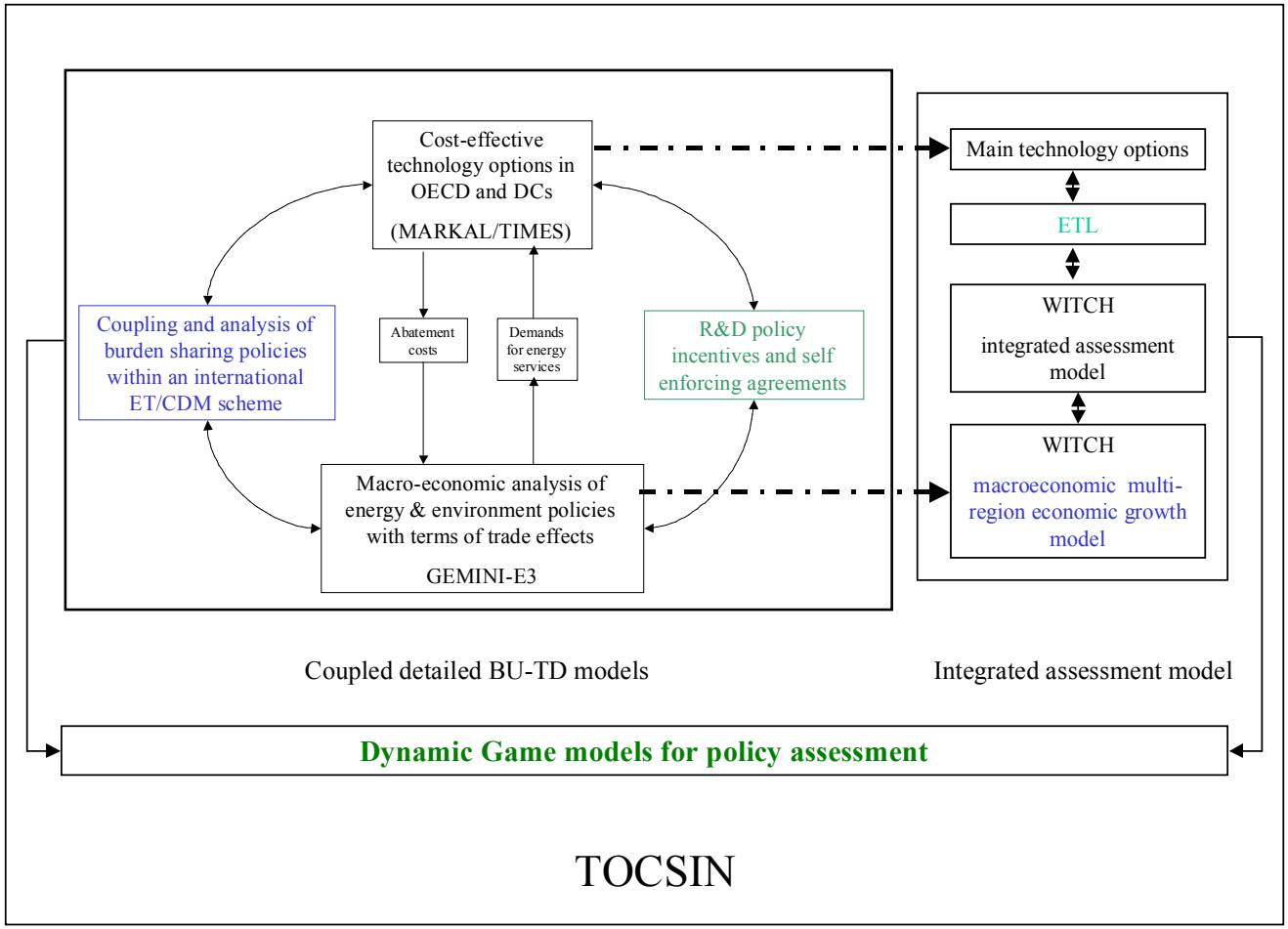
Research goals

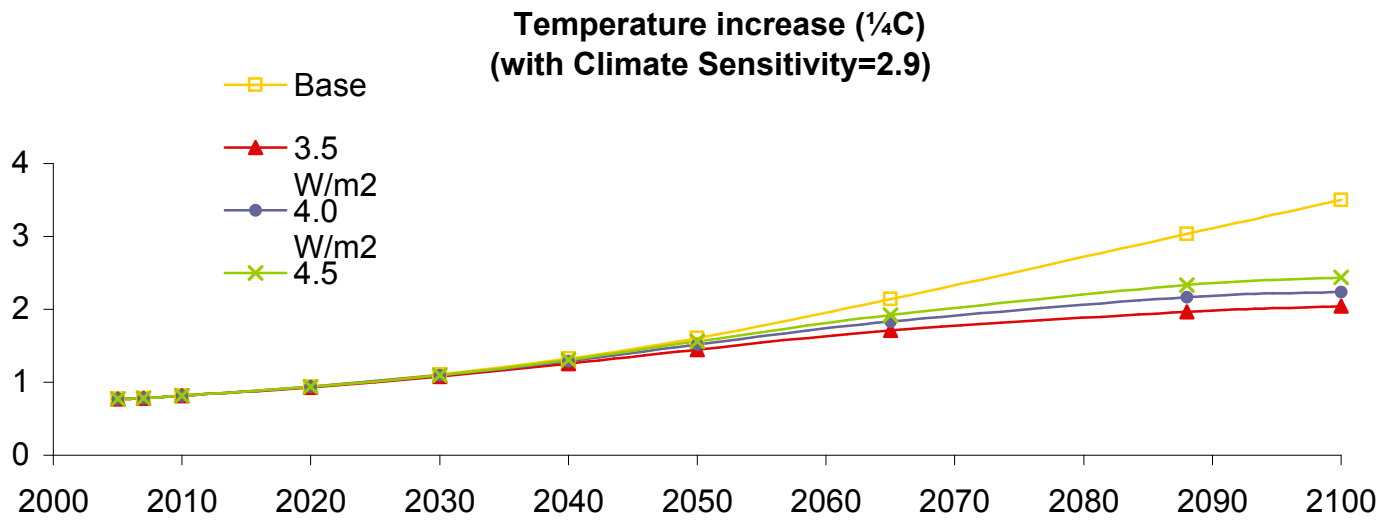
- Identify and assess technology options that might significantly reduce greenhouse gases (GHG) emissions in China and India in key sectors;
- Define the strategic dimension of RD&D cooperation and incentives for the participation of developing countries (DCs) in post-2012 GHG emissions reduction strategies and technological cooperation.
- Evaluate how Clean Development Mechanism (CDM) and international emission trading (IET) might improve the attractiveness of new energy technology options for DCs, and thus contribute to stimulate RD&D cooperation and technology transfers toward China and India.

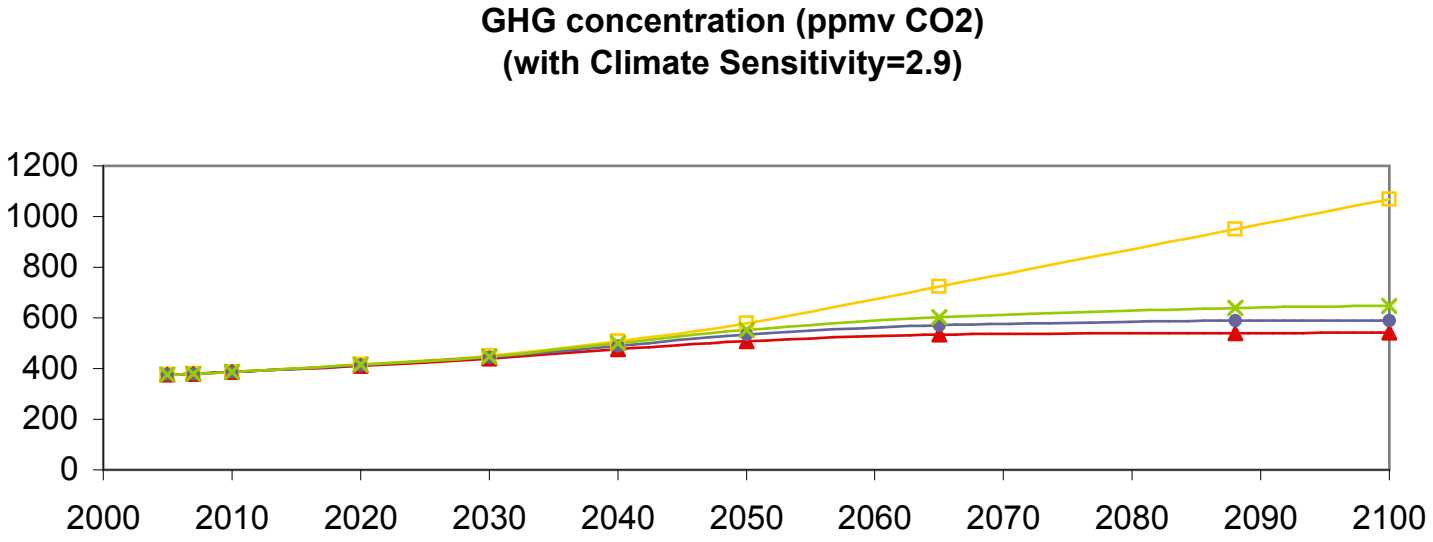
Modelling tools



Global climate constraint

How to limit radiative forcing to 3.5 W/m2


Temperature increase (¼C)
(with Climate Sensitivity=2.9)
Base
3.5 W/m2
4.0 W/m2
4.5
0
1
2
3
4
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100


GHG concentration (ppmv CO2)
(with Climate Sensitivity=2.9)
0
200
400
600
800
1000
1200
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100

GHG concentration path & cumulative emissions

Concentrations in ppmv		2005	2007	2010	2020	2030	2040	2050	2065	2088	2100
CO2_EQ	**Base**	**376**	**380**	**387**	**416**	**449**	**508**	**578**	**725**	**951**	**1068**
	3.5 W/m2	**376**	**380**	**386**	**412**	**440**	**475**	**507**	**534**	**540**	**543**
	4.0 W/m2	**376**	**380**	**387**	**414**	**445**	**490**	**533**	**571**	**590**	**589**
	4.5 W/m2	**376**	**380**	**387**	**415**	**448**	**500**	**552**	**603**	**639**	**647**

Cumulative emissions of GHG		2005	2008	2012	2027	2033	2046	2054	2076	2100
GtC-eq	TO_BASE3	8.885	35.597	72.589	238.182	329.891	591.375	807.095	1551.237	2595.242
GtC-eq	TO_F3p5	8.857	35.266	71.341	220.606	296.402	465.299	565.766	783.478	938.630
GtC-eq	TO_F4p0	8.880	35.527	72.152	232.048	315.588	522.707	654.374	927.402	1145.103
GtC-eq	TO_F4p5	8.883	35.742	72.844	237.278	326.666	560.703	717.055	1050.856	1351.974

Obtained from TIAM runs.

Global cost of abatement

Global loss of Surplus NPV in T$			% GDP
	TO_BASE3	0.00	
	TO_F3p5	10.13	3.2%
	TO_F4p0	5.45	1.7%
	TO_F4p5	2.57	0.8%

Annualized per capita loss over 96 years (assume an average 9 Billion inhabitants)		
	TO_BASE3	$0
	TO_F3p5	$57
	TO_F4p0	$31
	TO_F4p5	$14

Abatement cost

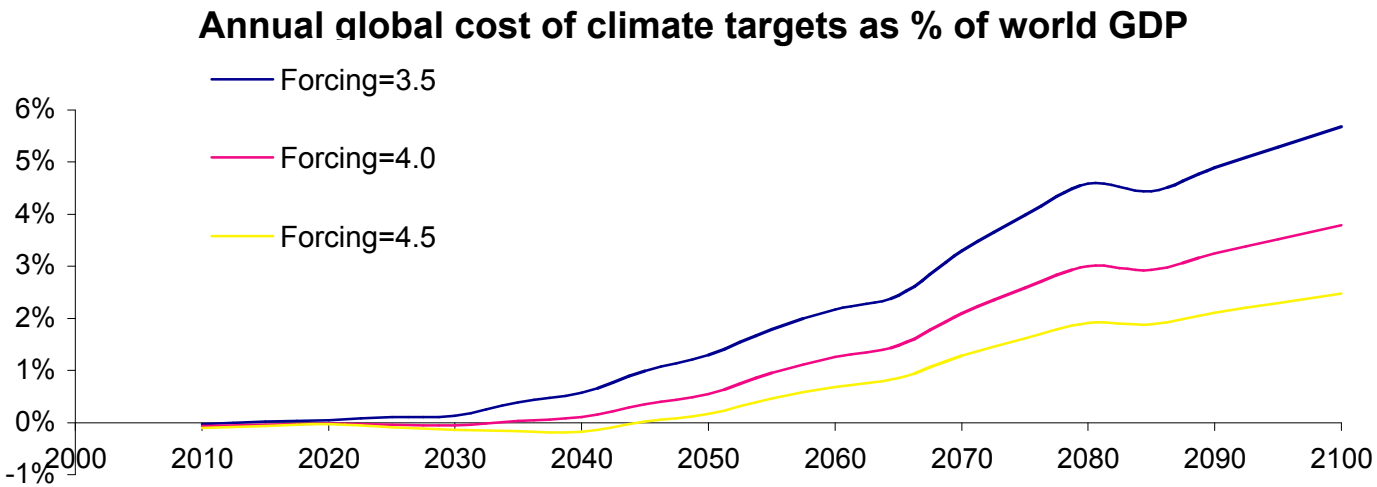
Distribution among groups of countries

Price of oil & gas energy

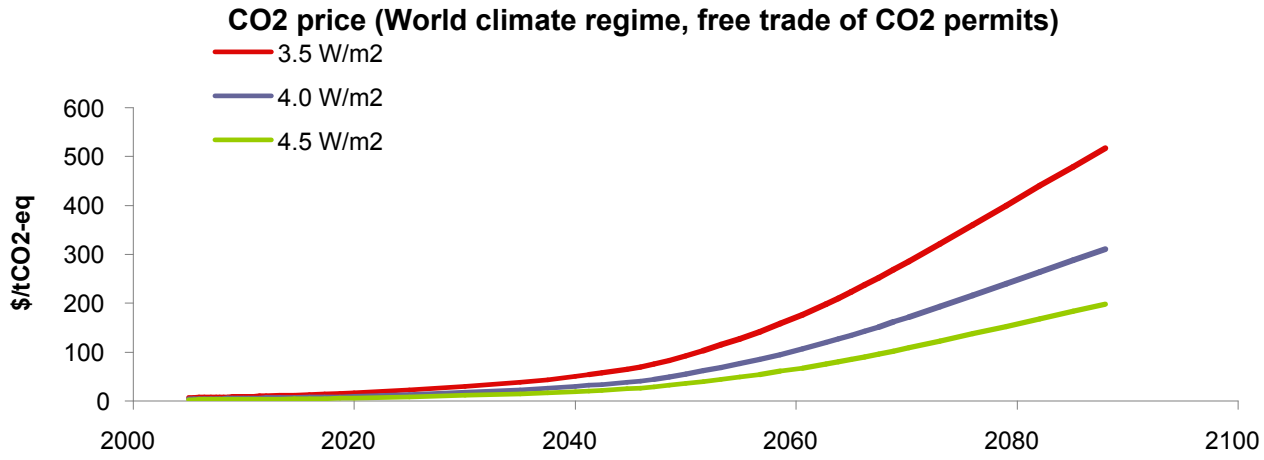
Oil and Gas prices ($/GJ)

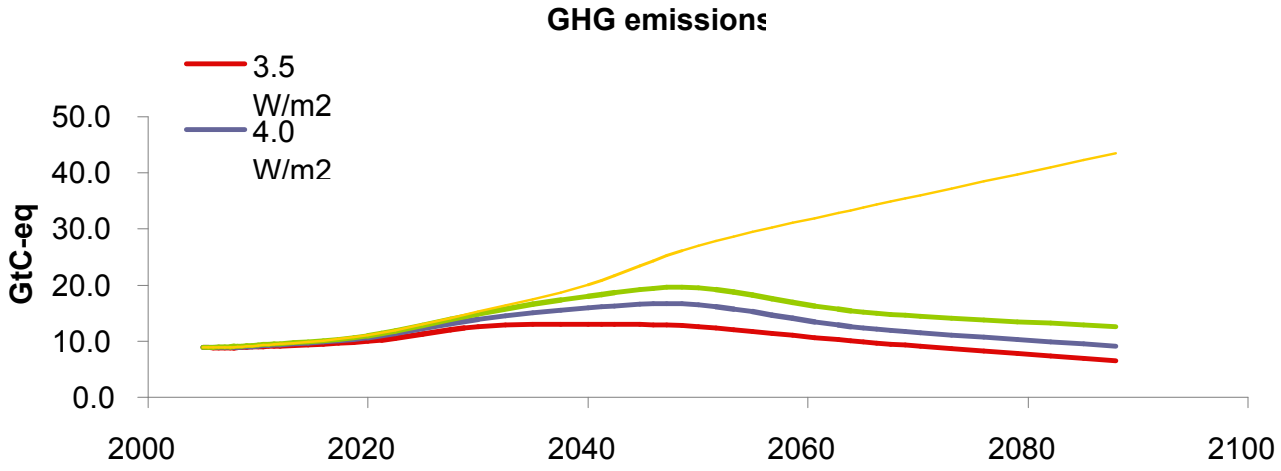
	Crude oil	Natural gas		
		Europe	Asia	America
2010	8.03	4.87	5.23	5.10
2020	7.60	5.12	5.01	5.61
2030	8.33	6.45	7.61	7.22
2040	11.15	7.08	8.93	7.71
2050	12.89	8.81	10.52	8.99

Cost evolution



Carbon price in a World IET





WORLD

Table Name: _Discounted cost regional
Active Unit: M Euro

ScenarioDesc	Attribute	Commodity	PV
TO_BASE3	Reg_obj	-	234043349
TO_BASE3	Reg_wobj	ELS	0
TO_BASE3	Reg_wobj	FIX	24365359
TO_BASE3	Reg_wobj	INV	154973286
TO_BASE3	Reg_wobj	VAR	54704705
TO_BASE3	Reg_wobj	VARX	0
TO_F3p5	Reg_obj	-	244170252
TO_F3p5	Reg_wobj	ELS	4353134
TO_F3p5	Reg_wobj	FIX	23636899
TO_F3p5	Reg_wobj	INV	160294719
TO_F3p5	Reg_wobj	VAR	55885500
TO_F3p5	Reg_wobj	VARX	0

10126903 Loss of surplus 3p5 vs BASE

5321433 Need of INV

52.5% % vs total cost

INDIA AND CHINA

Table Name: _Discounted cost regional
Active Unit: M Euro

Region	ScenarioDesc	Attribute	Commodity	PV		
CHI	TO_BASE3	Reg_obj	-	34211197		
CHI	TO_BASE3	Reg_wobj	ELS	0		
CHI	TO_BASE3	Reg_wobj	FIX	3848242		
CHI	TO_BASE3	Reg_wobj	INV	24482067		
CHI	TO_BASE3	Reg_wobj	VAR	5880888		
CHI	TO_BASE3	Reg_wobj	VARX	0		
CHI	TO_F3p5	Reg_obj	-	36923939	2712741	
CHI	TO_F3p5	Reg_wobj	ELS	2178497		
CHI	TO_F3p5	Reg_wobj	FIX	3397444		
CHI	TO_F3p5	Reg_wobj	INV	24949464	467397	
CHI	TO_F3p5	Reg_wobj	VAR	6398534	17.2%	Share of the CHI cost
CHI	TO_F3p5	Reg_wobj	VARX	0	8.8%	Share of the World INV increase
IND	TO_BASE3	Reg_obj	-	11576777		
IND	TO_BASE3	Reg_wobj	ELS	0		
IND	TO_BASE3	Reg_wobj	FIX	1210857		
IND	TO_BASE3	Reg_wobj	INV	8893410		
IND	TO_BASE3	Reg_wobj	VAR	1472509		
IND	TO_BASE3	Reg_wobj	VARX	0		
IND	TO_F3p5	Reg_obj	-	13435307	1858530	
IND	TO_F3p5	Reg_wobj	ELS	470947		
IND	TO_F3p5	Reg_wobj	FIX	1374306		
IND	TO_F3p5	Reg_wobj	INV	9782921	889510	
IND	TO_F3p5	Reg_wobj	VAR	1807133	47.9%	Share of the IND cost
IND	TO_F3p5	Reg_wobj	VARX	0	16.7%	Share of the World INV increase

WEU

Table Name: _Discounted cost regional
Active Unit: M Euro

Region	ScenarioDesc	Attribute	Commodity	PV
WEU	TO_BASE3	Reg_obj	-	21137158.3
WEU	TO_BASE3	Reg_wobj	ELS	0
WEU	TO_BASE3	Reg_wobj	FIX	2395572.43
WEU	TO_BASE3	Reg_wobj	INV	16617033
WEU	TO_BASE3	Reg_wobj	VAR	2124552.87
WEU	TO_BASE3	Reg_wobj	VARX	0
WEU	TO_F3p5	Reg_obj	-	21951901.3
WEU	TO_F3p5	Reg_wobj	ELS	188580.863
WEU	TO_F3p5	Reg_wobj	FIX	2428250.62
WEU	TO_F3p5	Reg_wobj	INV	17132203.9
WEU	TO_F3p5	Reg_wobj	VAR	2202865.98
WEU	TO_F3p5	Reg_wobj	VARX	0

814743

515171

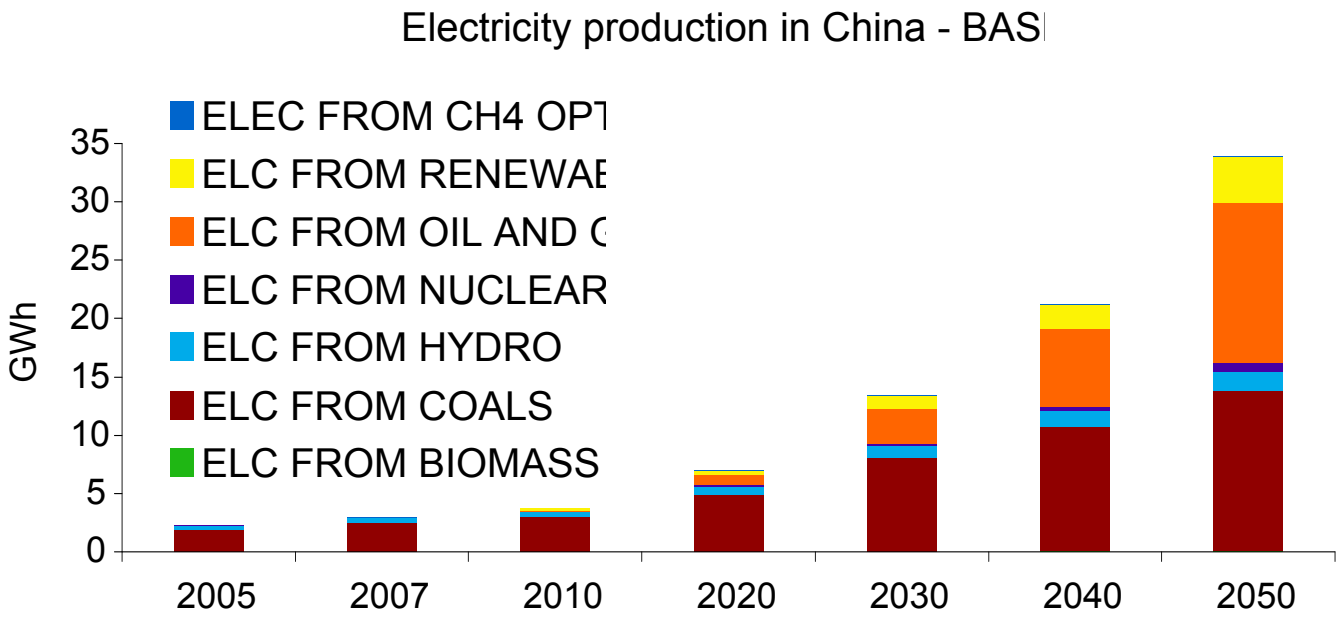
63.2% Share of the WEU cost

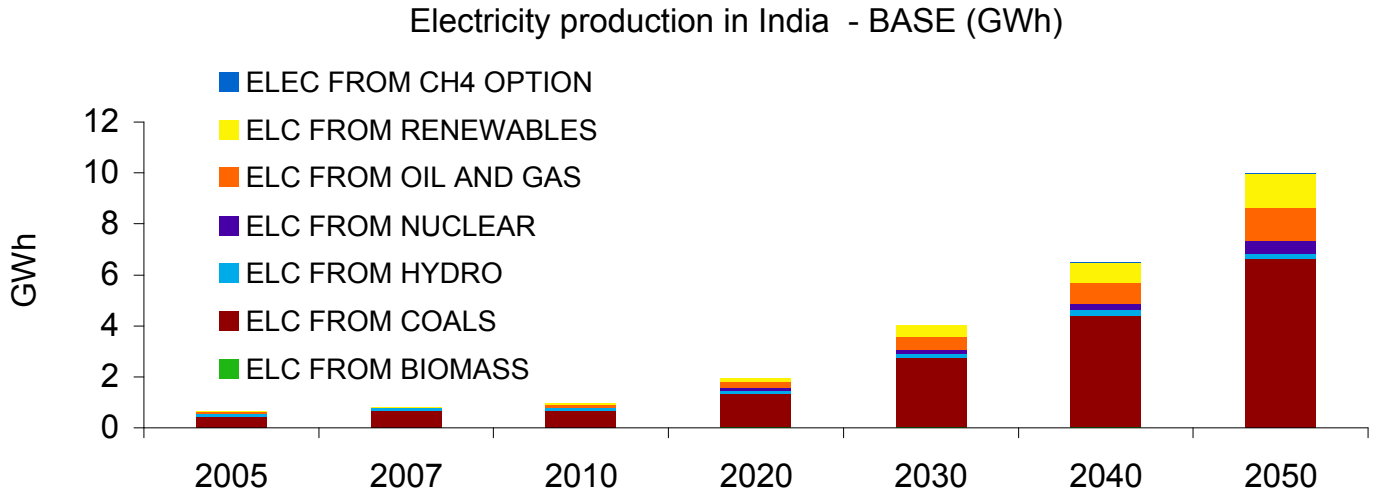
9.7% Share of the World INV increase

Technology choices

China & India

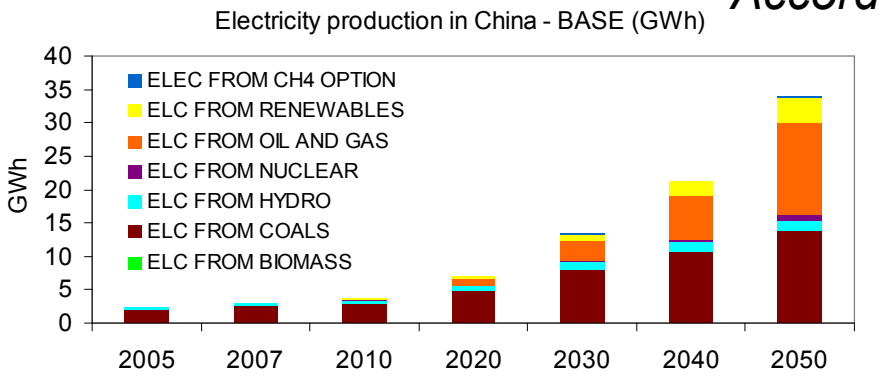
For electricity production

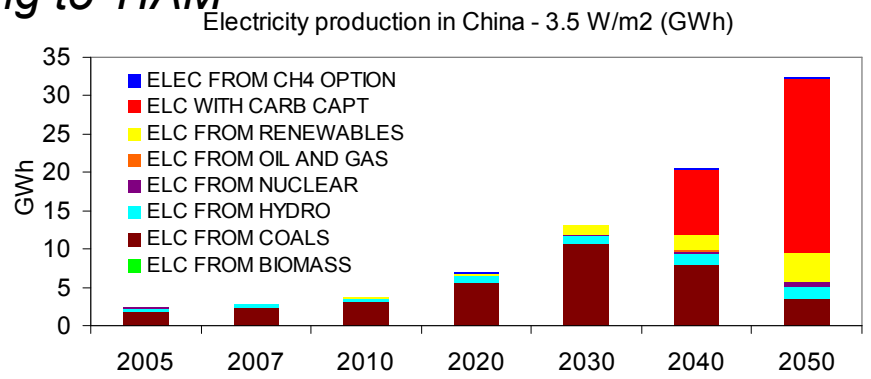

Electricity production in China - BAS
ELEC FROM CH4 OPT
ELC FROM RENEWAE
ELC FROM OIL AND G
ELC FROM NUCLEAR
ELC FROM HYDRO
ELC FROM COALS
ELC FROM BIOMASS
GWh
35
30
25
20
15
10
5
0
2005
2007
2010
2020
2030
2040
2050

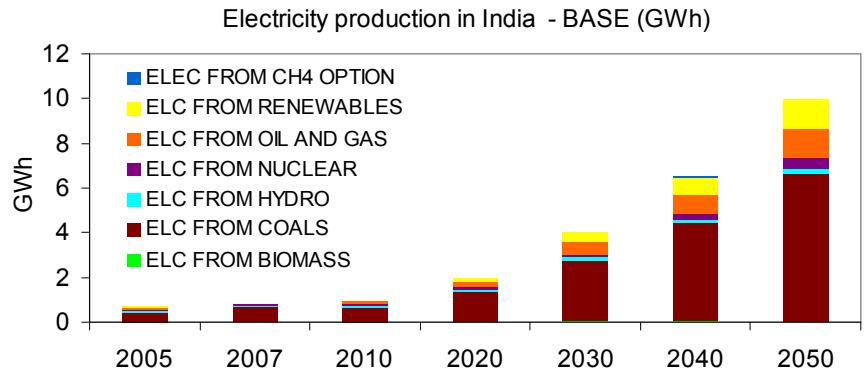

Electricity production in India - BASE (GWh)
ELEC FROM CH4 OPTION
ELC FROM RENEWABLES
ELC FROM OIL AND GAS
ELC FROM NUCLEAR
ELC FROM HYDRO
ELC FROM COALS
ELC FROM BIOMASS
GWh
12
10
8
6
4
2
0
2005
2007
2010
2020
2030
2040
2050

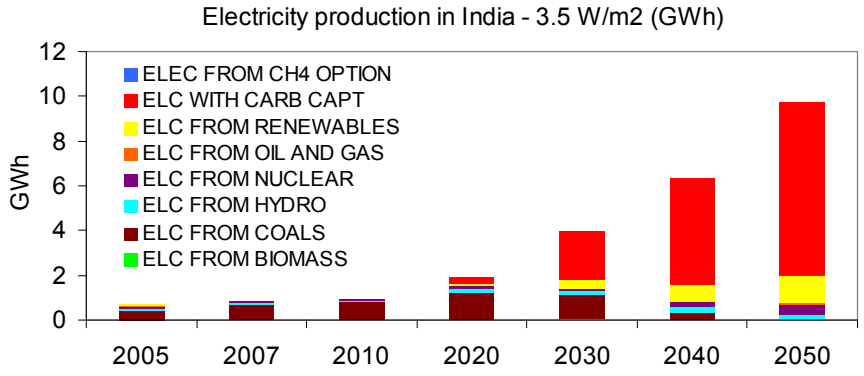
From Base to 3.5 W/m2

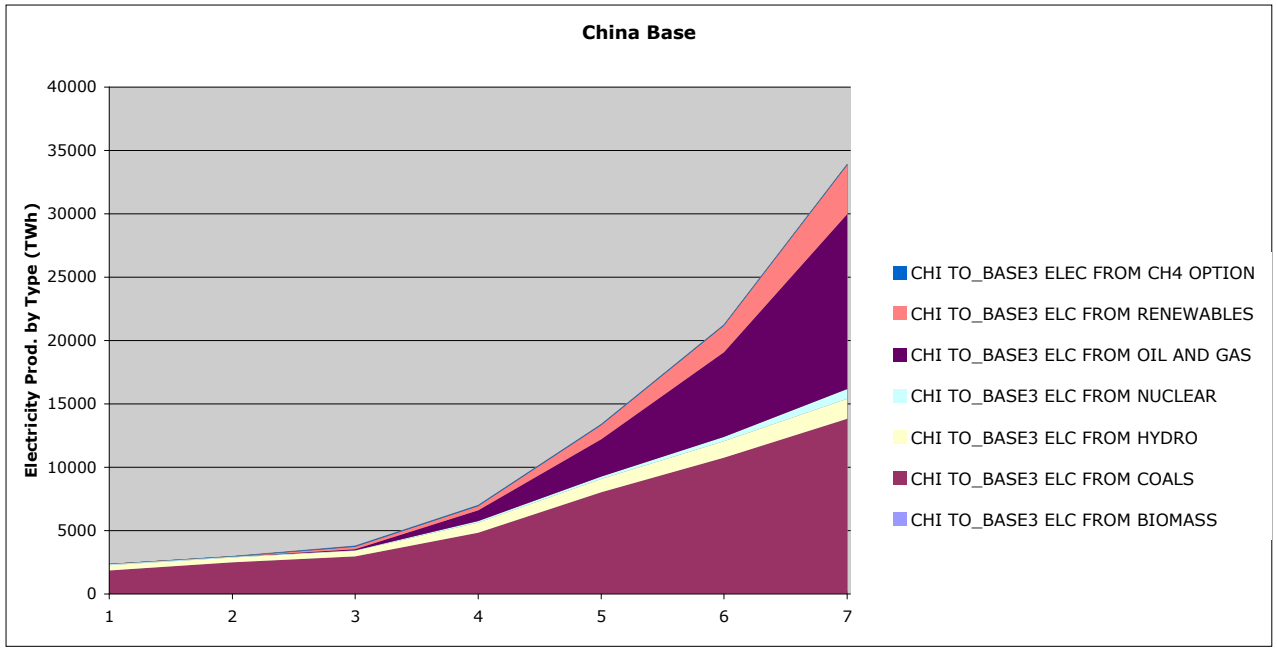
According to TIAM

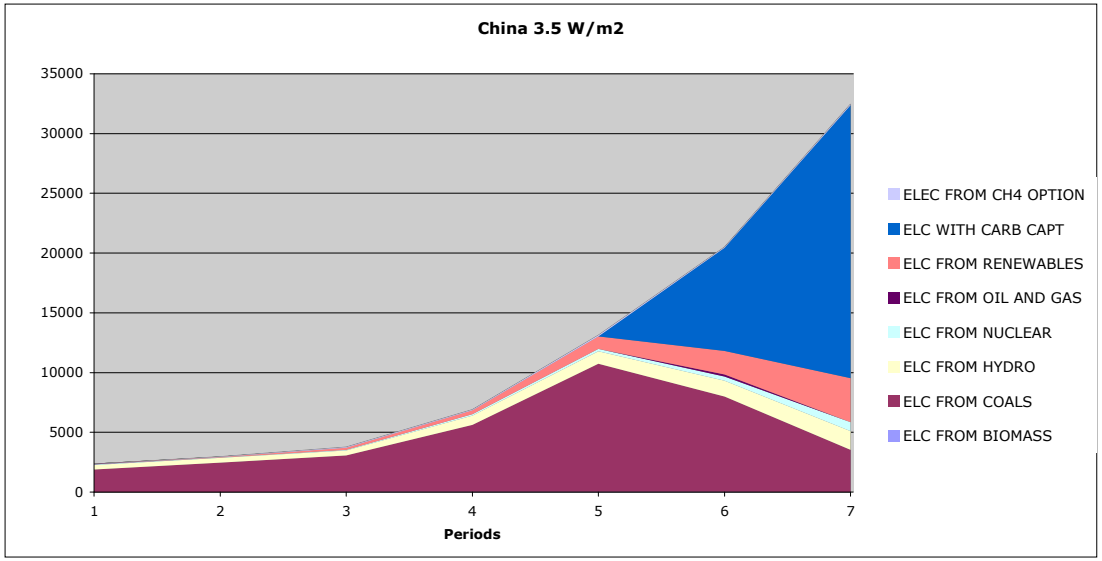


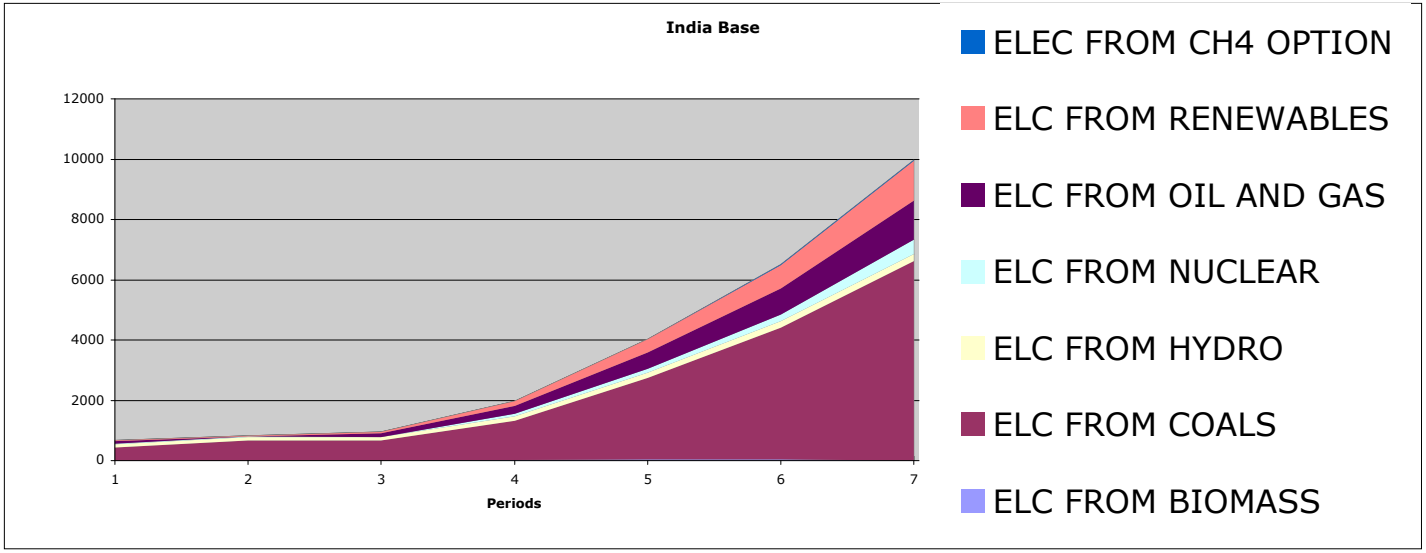


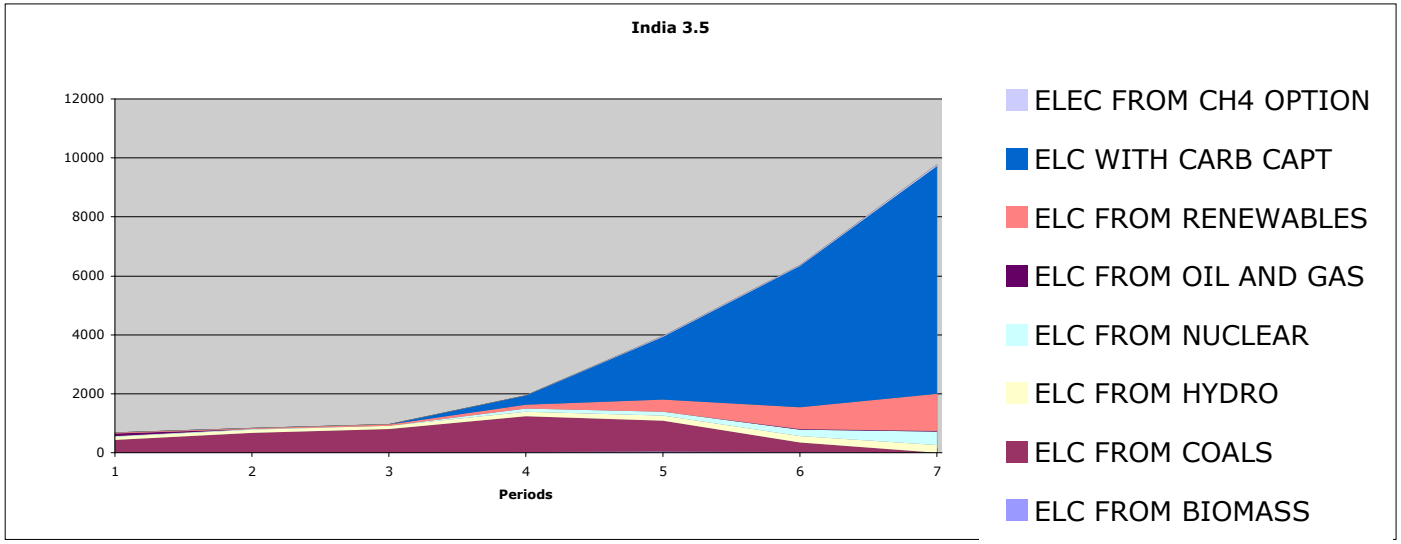





China Base
Electricity Prod. by Type (TWh)
40000
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
CHI TO_BASE3 ELEC FROM CH4 OPTION
CHI TO_BASE3 ELC FROM RENEWABLES
CHI TO_BASE3 ELC FROM OIL AND GAS
CHI TO_BASE3 ELC FROM NUCLEAR
CHI TO_BASE3 ELC FROM HYDRO
CHI TO_BASE3 ELC FROM COALS
CHI TO_BASE3 ELC FROM BIOMASS


China 3.5 W/m2
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
Periods
ELEC FROM CH4 OPTION
ELC WITH CARB CAPT
ELC FROM RENEWABLES
ELC FROM OIL AND GAS
ELC FROM NUCLEAR
ELC FROM HYDRO
ELC FROM COALS
ELC FROM BIOMASS


India Base
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
Periods
ELEC FROM CH4 OPTION
ELC FROM RENEWABLES
ELC FROM OIL AND GAS
ELC FROM NUCLEAR
ELC FROM HYDRO
ELC FROM COALS
ELC FROM BIOMASS


India 3.5
12000
10000
8000
6000
4000
2000
0
1
2
3
4
5
6
7
Periods
ELEC FROM CH4 OPTION
ELC WITH CARB CAPT
ELC FROM RENEWABLES
ELC FROM OIL AND GAS
ELC FROM NUCLEAR
ELC FROM HYDRO
ELC FROM COALS
ELC FROM BIOMASS

Budget Sharing Game

Equilibrium under constraints

(quotas are the strategic variables)

Game with constraints

- One first considers the time horizon **2010-2050** and one identifies the total amount of GHG emissions, at world level, that is compatible with maintaining the SAT increase below 2ºC. This global budget has been evaluated to be **519 GtC** equiv.
- One distributes this global amount among the different parties in an international agreement. One may expect that this distribution of effort will be the key element in the forthcoming climate negotiations.
- For a given split of the total GHG emissions allowance, one solves a ***dynamic non-cooperative game*** where the decision variables are ***schedules of GHG quotas***, payoffs are ***welfare gains*** (or loss), while respecting the allocated cumulative emissions budget, and **after implementing an international emissions trading scheme**.

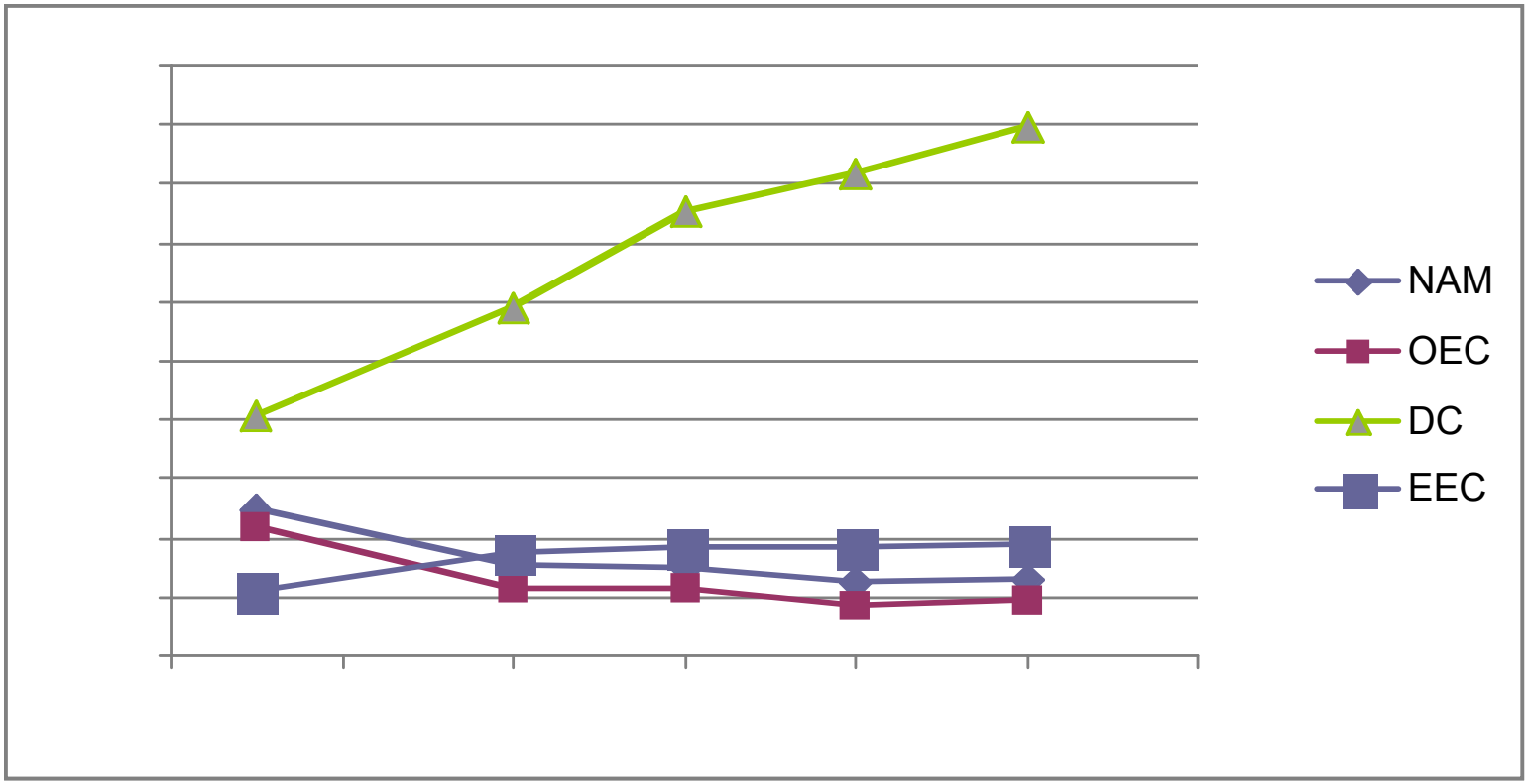
Groups of Countries

Region		Regions in TIMES
ALENA + Australia	NAM	USA CAN MEX AUS
Other OECD	OEC	WEU EEU JAP
Developing Countries	PVD	CSA AFR IND SKO CHI ODA
Oil & Gas exporting countrie	EEC	FSU MEA

Allocation and payoffs

	2005	2020	2030	2040	2050	constraints	sum emissions	Welfare surplus
NAM	2491.73	1517.43	1461.18	1239.18	1266.96	73	73.00	-1,379,476.00
OEC	2186.97	1129.92	1157.67	857.76	931.93	57	57.00	-887,056.30
DC	4060.76	5892.37	7547.25	8157.91	8953.22	311	310.90	907,392.12
EEC	1067.10	1751.92	1808.38	1811.72	1897.00	77	77.00	145,269.49

Equilibrium quotas



Groups of Countries

	TIAM	*GEMINI*	*WITCH*
IC1	USA CAN AUS	USA CAN AUZ	USA KOSAU
IC2	WEU EEU JAP SKO	EU-25 CHE JAP	CAJAZ OLDEURO NEWEURO
DC	AFR IND ODA	AFR IND ODA XSU LAT ASI	EASIA SSA SASIA
NIC	FSU CSA CHI MEA MEX	RUS XEU CHI BRA MEX VEN TUR MID	CHINA MENA LACA TE

Burden sharing rules

QUOTAS

	POPULATION	EMISSION	GDP	(50%pop, 25%emi, 25%gdp)	(50%pop, 50%emi)	V C&C 2050	V C&C 2100
IC1	**29**	**129**	**42**	**57**	**79**	**88**	**67**
IC2	**50**	**95**	**-12**	**46**	**72**	**78**	**62**
DCS	**268**	**133**	**179**	**212**	**200**	**151**	**202**
NIC	**172**	**162**	**309**	**204**	**168**	**202**	**188**
	519	519	518	519	519	519	519

C&C: starting on the basis of base year emissions and converging to equal per capita allocation

C&C 2050 or 2100

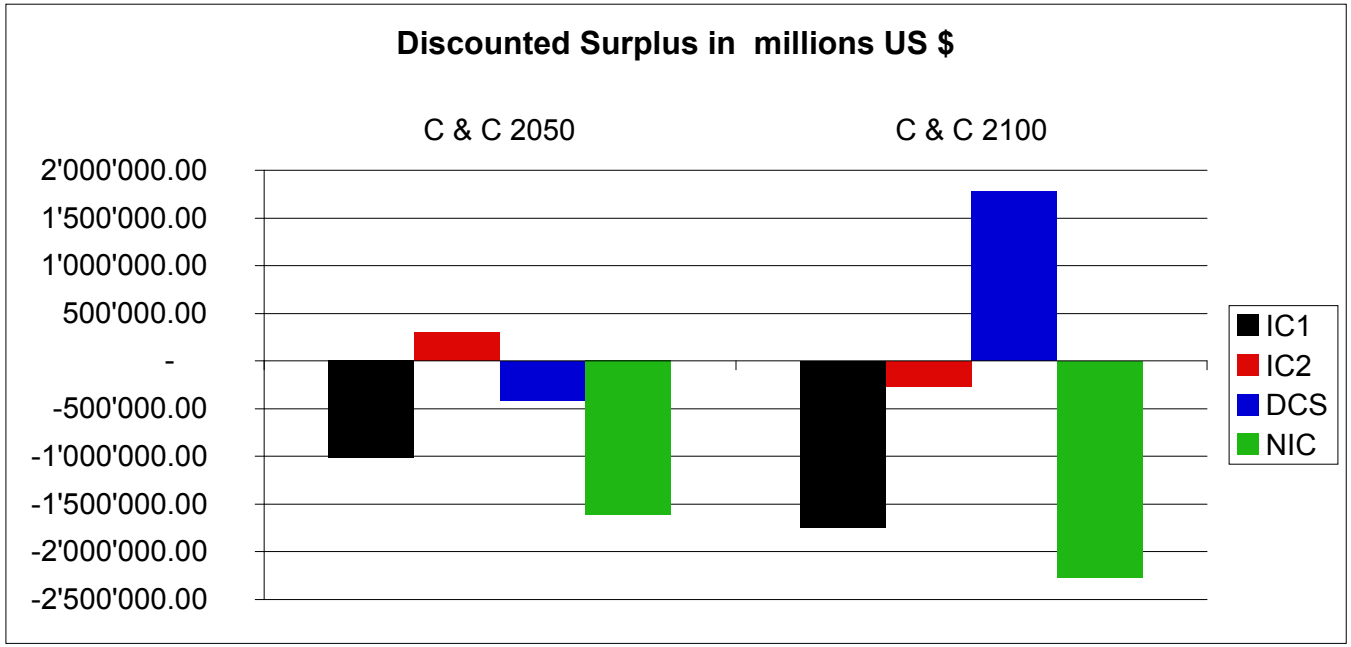
V C&C 2050

	2005	2020	2030	2040	2050	constraint	sum quotas	surplus
IC1	2277.778	1896.683	1933.51	1736.581	1683.223	**88**	88.00	-1'020'601.00
IC2	1648.5289	1678.207	1716.197	1682.693	1799.979	**78**	77.99	301'864.73
DCS	2544.78	2694.026	3454.862	3776.878	4659.54	**151**	151.00	-414'567.60
NIC	3341.4571	3480.527	4639.38	5204.629	6315.615	**202**	202.00	-1'614'727.00
	9812.544	9749.443	11743.949	12400.781	14458.357	519	518.98	

V C&C 2100

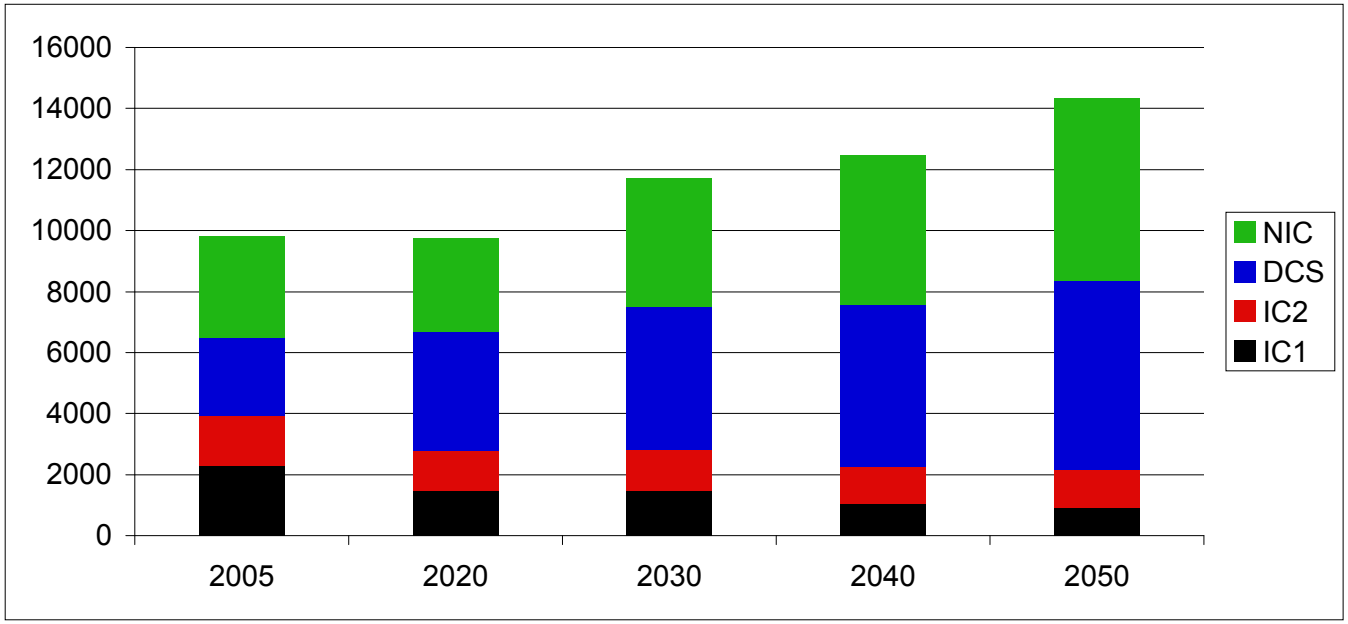
	2005	2020	2030	2040	2050	constraint	sum emissions	surplus
IC1	2277.778	1457.351	1468.191	1057.157	914.8631	**67**	67.00	-1'742'873.00
IC2	1648.5289	1337.158	1340.324	1194.254	1215.21	**62**	61.99	-266'669.50
DCS	2544.78	3881.17	4668.371	5326.168	6238.557	**202**	201.95	1'781'023.60
NIC	3341.4571	3079.892	4229.888	4908.988	5967.469	**188**	188.00	-2'272'658.00
	9812.544	9755.571	11706.774	12486.567	14336.099	519	518.94	

Discounted Surplus



		C & C 2050		C & C 2100
IC1	-	1'020'601.00	-	1'742'873.00
IC2		301'864.73	-	266'669.50
DCS	-	414'567.60		1'781'023.60
NIC	-	1'614'727.00	-	2'272'658.00

Equil. Quotas C&C 2100



	2005	2020	2030	2040	2050
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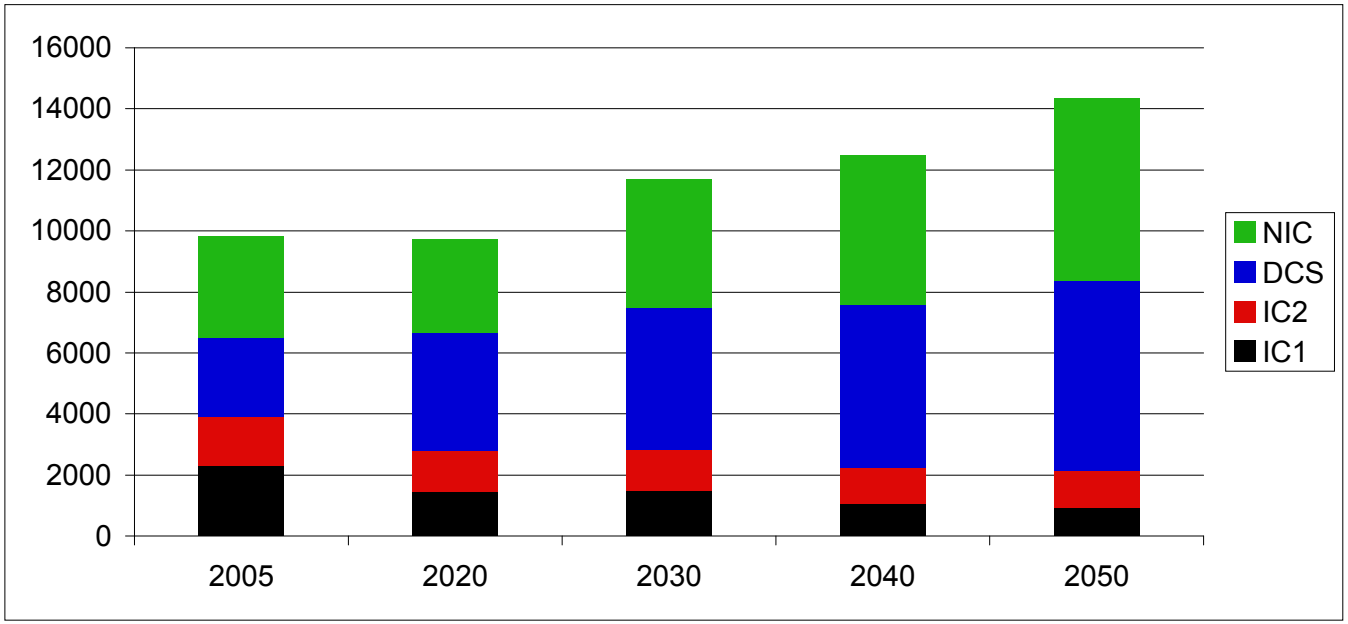
DCS	2544.78	3881.17	4668.371	5326.168	6238.557
NIC	3341.4571	3079.892	4229.888	4908.988	5967.469

Equil. Quotas C&C 2050



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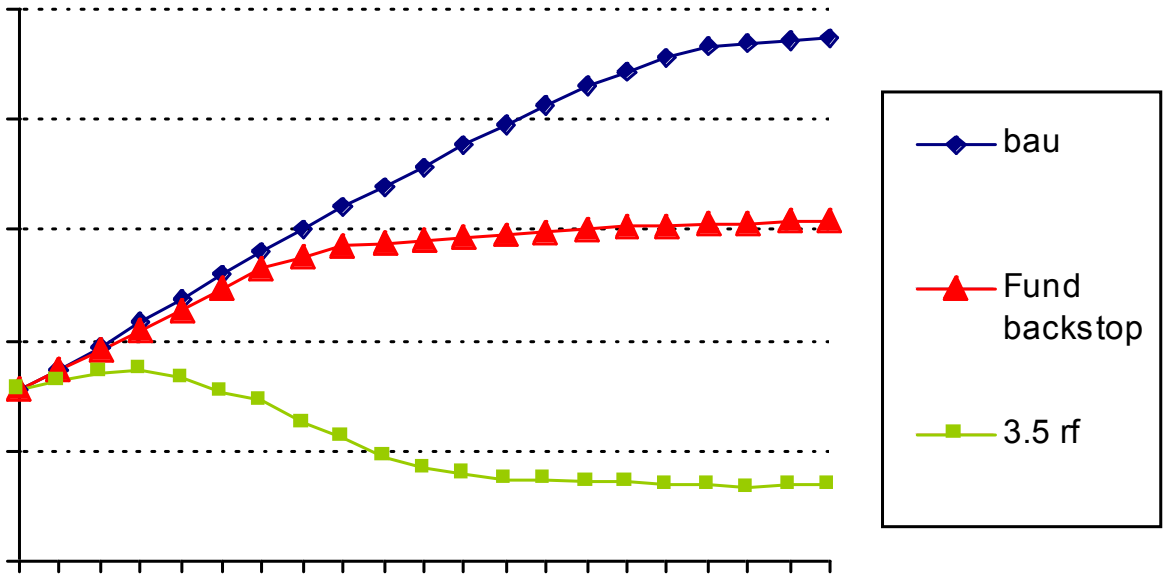
IC1	2277.778	1896.683	1933.51	1736.581	1683.223
IC2	1648.5289	1678.207	1716.197	1682.693	1799.979
DCS	2544.78	2694.026	3454.862	3776.878	4659.54
NIC	3341.4571	3480.527	4639.38	5204.629	6315.615

A global policy to accelerate the introduction of carbon free backstop technologies. A WITCH analysis


bau
Fund backstop
3.5 rf