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## EMF 22: Climate Policy Scenarios for Stabilisation and in Transition

Tsukuba International Congress Center (Epochal)  
Tsukuba, Japan  
December 12-14, 2006

Claudia Kemfert & Truong Truong

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## Climate Policy, R&D and the EU-ETS

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# European Emissions Trading System (EU-ETS)

- \* “The Environmental and Economic Effects of European Emissions Trading”, by Claudia Kemfert, Michael Kohlhaas, Truong Truong, and Artem Protsenko (forthcoming in *Climate Policy*). [KKTP]
- \* “Over-Allocation or Abatement? A Preliminary Analysis of the Eu Ets Based on the 2005 Emissions Data”, by Denny Ellerman and Barbara Buchner FEEM Working Paper 139.2006, November 2006. [EB]

## Percentage change in emissions for period 2005-2007 (\*)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-ile	Oth_Ind				
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9					
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3				
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1				
fin	-12.5												
fra	-0.4	-2.8	-10.3	-8.1									
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2				
grc	-6.5	-16.8			-6.6								
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5					
ita	-5.5		-4.2	-1.7	-3.4								
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8				
prt	-6.2			-1.2									
esp	-6.5	-3.6	-2.9	-5.4	-4.5								
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9				
cze	-4.5	-4.3	-4.6	-4.5	-4.1								
hun	-3.1	-5.1	-5.1	-5.1	-5.1								
pol	-9.3	-3.8	-10.3	-2	-7.5								

(\*) (Allocated emissions – Projected Emissions)/(Projected Emissions) \* 100



## Marginal Abatement Cost (\$/t CO2)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading			
										Domestic			
aut	3.8	42.2	1.6	3.0	1.0	2.0	3.2	2.0		3.7			
bel	11.5	32.3	1.6	4.4	3.2	5.7	6.4	3.5	7.7	8.0			
dnk	7.5	50.5	0.2	1.1	0.1		9.4		0.1	6.1			
fin	8.0									8.0			
fra	0.5	17.3	4.1	11.6						2.0			
deu	1.6	22.5	0.7	0.5	0.7	1.5	2.4	1.4	1.8	1.5			
grc	2.8	137.0			0.7					3.5			
gbr	2.2	13.3	0.4	0.3			0.2			0.8			
ita	2.8		2.1	2.6	1.7					2.6			
nld	3.8	30.7	1.8	8.7	1.1	0.2		0.4	13.9	3.5			
prt	2.0			1.6						2.0			
esp	2.3	19.2	1.3	6.8	3.4					2.8			
swe	5.1	163.1	10.7	16.2	15.0	13.4	26.9	18.7	8.8	8.4			
cze	1.1	53.8	1.3	2.5	1.4					1.2			
hun	1.0	28.6	1.9	3.9	1.9					1.3			
pol	2.3	45.8	2.9	1.3	2.6					2.2			

## Marginal Abatement Cost (\$/t CO2)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading			
										Domestic	Regional		
aut	3.8	42.2	1.6	3.0	1.0	2.0	3.2	2.0		3.7	2.0		
bel	11.5	32.3	1.6	4.4	3.2	5.7	6.4	3.5	7.7	8.0	2.0		
dnk	7.5	50.5	0.2	1.1	0.1		9.4		0.1	6.1	2.0		
fin	8.0									8.0	2.0		
fra	0.5	17.3	4.1	11.6						2.0	2.0		
deu	1.6	22.5	0.7	0.5	0.7	1.5	2.4	1.4	1.8	1.5	2.0		
grc	2.8	137.0			0.7					3.5	2.0		
gbr	2.2	13.3	0.4	0.3			0.2			0.8	2.0		
ita	2.8		2.1	2.6	1.7					2.6	2.0		
nld	3.8	30.7	1.8	8.7	1.1	0.2		0.4	13.9	3.5	2.0		
prt	2.0			1.6						2.0	2.0		
esp	2.3	19.2	1.3	6.8	3.4					2.8	2.0		
swe	5.1	163.1	10.7	16.2	15.0	13.4	26.9	18.7	8.8	8.4	2.0		
cze	1.1	53.8	1.3	2.5	1.4					1.2	2.0		
hun	1.0	28.6	1.9	3.9	1.9					1.3	2.0		
pol	2.3	45.8	2.9	1.3	2.6					2.2	2.0		

## Marginal Abatement Cost (\$/t CO2)

¥Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading		over (+) or under (-) allocation	
										Domestic	Regio-nal	from MAC consideration	
aut	3.8	42.2	1.6	3.0	1.0	2.0	3.2	2.0		3.7	2.0	-	
bel	11.5	32.3	1.6	4.4	3.2	5.7	6.4	3.5	7.7	8.0	2.0	-	
dnk	7.5	50.5	0.2	1.1	0.1		9.4		0.1	6.1	2.0	-	
fin	8.0									8.0	2.0	-	
fra	0.5	17.3	4.1	11.6						2.0	2.0	+	
deu	1.6	22.5	0.7	0.5	0.7	1.5	2.4	1.4	1.8	1.5	2.0	+	
grc	2.8	137.0			0.7					3.5	2.0	-	
gbr	2.2	13.3	0.4	0.3			0.2			0.8	2.0	+	
ita	2.8		2.1	2.6	1.7					2.6	2.0	-	
nld	3.8	30.7	1.8	8.7	1.1	0.2		0.4	13.9	3.5	2.0	-	
prt	2.0			1.6						2.0	2.0	+	
esp	2.3	19.2	1.3	6.8	3.4					2.8	2.0	-	
swe	5.1	163.1	10.7	16.2	15.0	13.4	26.9	18.7	8.8	8.4	2.0	-	
cze	1.1	53.8	1.3	2.5	1.4					1.2	2.0	+	
hun	1.0	28.6	1.9	3.9	1.9					1.3	2.0	+	
pol	2.3	45.8	2.9	1.3	2.6					2.2	2.0		



## Percentage change in emissions for period 2005-2007 (\*)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading			
										Domestic Trading			
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		-4.3			
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-8.5			
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-15.1			
fin	-12.5									-6.2			
fra	-0.4	-2.8	-10.3	-8.1						-1.5			
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	-1.8			
grc	-6.5	-16.8			-6.6					-3.4			
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		-5.0			
ita	-5.5		-4.2	-1.7	-3.4					-2.5			
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-3.7			
prt	-6.2			-1.2						-2.5			
esp	-6.5	-3.6	-2.9	-5.4	-4.5					-3.2			
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-6.3			
cze	-4.5	-4.3	-4.6	-4.5	-4.1					-3.5			
hun	-3.1	-5.1	-5.1	-5.1	-5.1					-2.4			
pol	-9.3	-3.8	-10.3	-2	-7.5					-6.4			

(\*)  $(\text{Allocated emissions} - \text{Projected Emissions}) / (\text{Projected Emissions}) * 100$

## Percentage change in emissions for period 2005-2007 (\*)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-ile	Oth_Ind	Emissions Trading			
										Domestic Trading	Regional Trading		
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		-4.3	-2.0		
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-8.5	-2.4		
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-15.1	-6.2		
fin	-12.5									-6.2	-1.2		
fra	-0.4	-2.8	-10.3	-8.1						-1.5	-1.6		
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	-1.8	-2.7		
grc	-6.5	-16.8			-6.6					-3.4	-1.9		
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		-5.0	-8.7		
ita	-5.5		-4.2	-1.7	-3.4					-2.5	-1.9		
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-3.7	-2.2		
prt	-6.2			-1.2						-2.5	-2.6		
esp	-6.5	-3.6	-2.9	-5.4	-4.5					-3.2	-2.4		
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-6.3	-1.6		
cze	-4.5	-4.3	-4.6	-4.5	-4.1					-3.5	-7.4		
hun	-3.1	-5.1	-5.1	-5.1	-5.1					-2.4	-3.9		
pol	-9.3	-3.8	-10.3	-2	-7.5					-6.4	-6.0		

(\*)  $(\text{Allocated emissions} - \text{Projected Emissions}) / (\text{Projected Emissions}) * 100$

## Percentage change in emissions for period 2005-2007 (\*)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading		over (+) or under (-) allocation	
										Domestic Trading	Regional Trading	from ET consideration	
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		-4.3	-2.0	-2.3	
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-8.5	-2.4	-6.1	
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-15.1	-6.2	-8.9	
fin	-12.5									-6.2	-1.2	-5.0	
fra	-0.4	-2.8	-10.3	-8.1						-1.5	-1.6	+0.1	
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	-1.8	-2.7	+0.9	
grc	-6.5	-16.8			-6.6					-3.4	-1.9	-1.5	
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		-5.0	-8.7	+3.7	
ita	-5.5		-4.2	-1.7	-3.4					-2.5	-1.9	-0.6	
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-3.7	-2.2	-1.5	
prt	-6.2			-1.2						-2.5	-2.6	+0.1	
esp	-6.5	-3.6	-2.9	-5.4	-4.5					-3.2	-2.4	-0.8	
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-6.3	-1.6	-4.7	
cze	-4.5	-4.3	-4.6	-4.5	-4.1					-3.5	-7.4	+3.9	
hun	-3.1	-5.1	-5.1	-5.1	-5.1					-2.4	-3.9	+1.5	
pol	-9.3	-3.8	-10.3	-2	-7.5					-6.4	-6.0	-0.4	

(\*)  $(\text{Allocated emissions} - \text{Projected Emissions}) / (\text{Projected Emissions}) * 100$

## Percentage change in emissions for period 2005-2007 (\*)

Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading		over (+) or under (-) allocation	
										Domestic Trading	Regional Trading	from MAC consideration	from 2006 EU ETS data (**)
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		-4.3	-2.0	-2.3	-3.0%
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-8.5	-2.4	-6.1	5.0%
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-15.1	-6.2	-8.9	29.0%
fin	-12.5									-6.2	-1.2	-5.0	25.9%
fra	-0.4	-2.8	-10.3	-8.1						-1.5	-1.6	+0.1	12.7%
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	-1.8	-2.7	+0.9	4.2%
grc	-6.5	-16.8			-6.6					-3.4	-1.9	-1.5	-0.2%
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		-5.0	-8.7	+3.7	-17.7%
ita	-5.5		-4.2	-1.7	-3.4					-2.5	-1.9	-0.6	-4.4%
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-3.7	-2.2	-1.5	7.1%
prt	-6.2			-1.2						-2.5	-2.6	+0.1	1.3%
esp	-6.5	-3.6	-2.9	-5.4	-4.5					-3.2	-2.4	-0.8	-6.3%
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-6.3	-1.6	-4.7	13.3%
cze	-4.5	-4.3	-4.6	-4.5	-4.1					-3.5	-7.4	+3.9	14.9%
hun	-3.1	-5.1	-5.1	-5.1	-5.1					-2.4	-3.9	+1.5	13.9%
pol	-9.3	-3.8	-10.3	-2	-7.5					-6.4	-6.0	-0.4	12.8%

(\*\*) Table 1, Ellerman and Buchner (2006)

## Percentage change in emissions for period 2005-2007 (\*)

¥Sector Region	Electricity	Oil_Pets	Metals	Min_Prod	Paper	Motor_Equip	Constr	Tex-tile	Oth_Ind	Emissions Trading		over (+) or under (-) allocation	
										Domestic Trading	Regional Trading	from MAC consideration	from 2006 EU ETS data (**)
aut	-8.9	-7.9	-3.5	-4.3	-3.6	-4.9	-4.6	-5.9		-4.3	-2.0	-2.3	-3.0%
bel	-27.4	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-5.3	-8.5	-2.4	-6.1	5.0%
dnk	-26.2	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-7.1	-15.1	-6.2	-8.9	29.0%
fin	-12.5									-6.2	-1.2	-5.0	25.9%
fra	-0.4	-2.8	-10.3	-8.1						-1.5	-1.6	+0.1	12.7%
deu	-3.1	-2.6	-0.5	-0.4	-1	-2.2	-2.2	-2.2	-2.2	-1.8	-2.7	+0.9	4.2%
grc	-6.5	-16.8			-6.6					-3.4	-1.9	-1.5	-0.2%
gbr	-8.7	-0.9	-18.4	-5.7	-3.3	-3.3	-2.9	-2.5		-5.0	-8.7	+3.7	-17.7%
ita	-5.5		-4.2	-1.7	-3.4					-2.5	-1.9	-0.6	-4.4%
nld	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-3.7	-2.2	-1.5	7.1%
prt	-6.2			-1.2						-2.5	-2.6	+0.1	1.3%
esp	-6.5	-3.6	-2.9	-5.4	-4.5					-3.2	-2.4	-0.8	-6.3%
swe	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-13.9	-6.3	-1.6	-4.7	13.3%
cze	-4.5	-4.3	-4.6	-4.5	-4.1					-3.5	-7.4	+3.9	14.9%
hun	-3.1	-5.1	-5.1	-5.1	-5.1					-2.4	-3.9	+1.5	13.9%
pol	-9.3	-3.8	-10.3	-2	-7.5					-6.4	-6.0	-0.4	12.8%

(\*\*) Table 1, Ellerman and Buchner (2006)

# R & D, Climate Policy and Technological Change

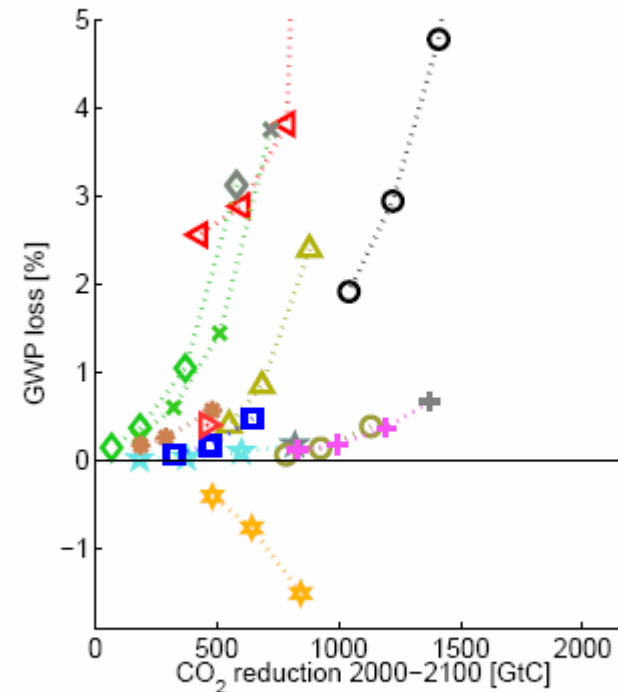
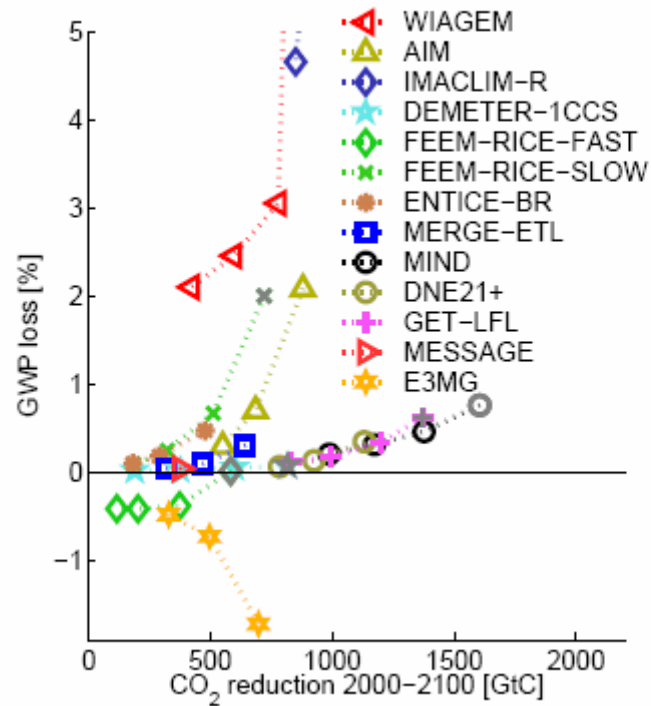
- **Uncertainty with respect to the concept of “Technological Change” or “Technological Progress”, especially when considered as “inducement” from climate policy.**

## Edenhofer *et al.* (2005) (\*)

- Despite considerable progress in ETC (or ITC) research, discrepancies among models and uncertainties of model results remain significant
  - *parameter uncertainty*
  - structural uncertainty or *model uncertainty*.

**(\*)**“**Induced Technological Change: Exploring its Implications for the Economics of Atmospheric Stabilization**”, **Synthesis Report from the Innovation Modelling Comparison Project (IMCP)**, by *Ottmar Edenhofer, Kai Lessmann, Claudia Kemfert, Michael Grubb and Jonathan Koehler*

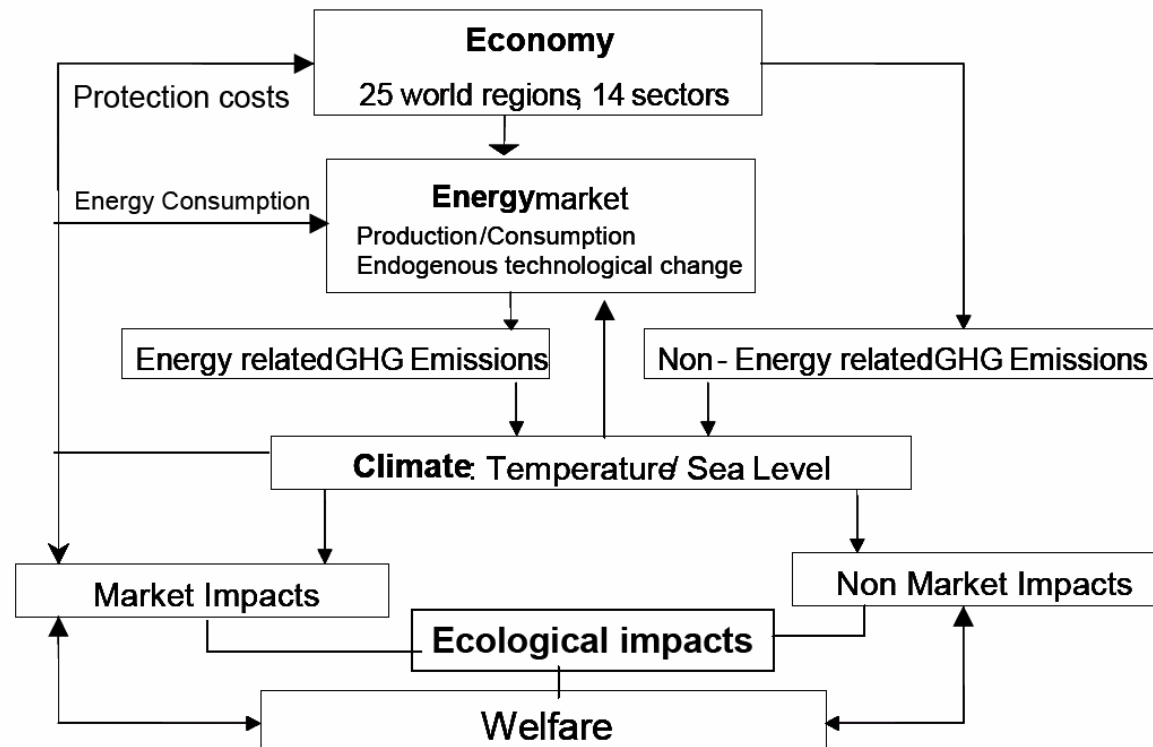
Edenhofer *et al.* (2005)



b



# WIAGEM



# WIAGEM

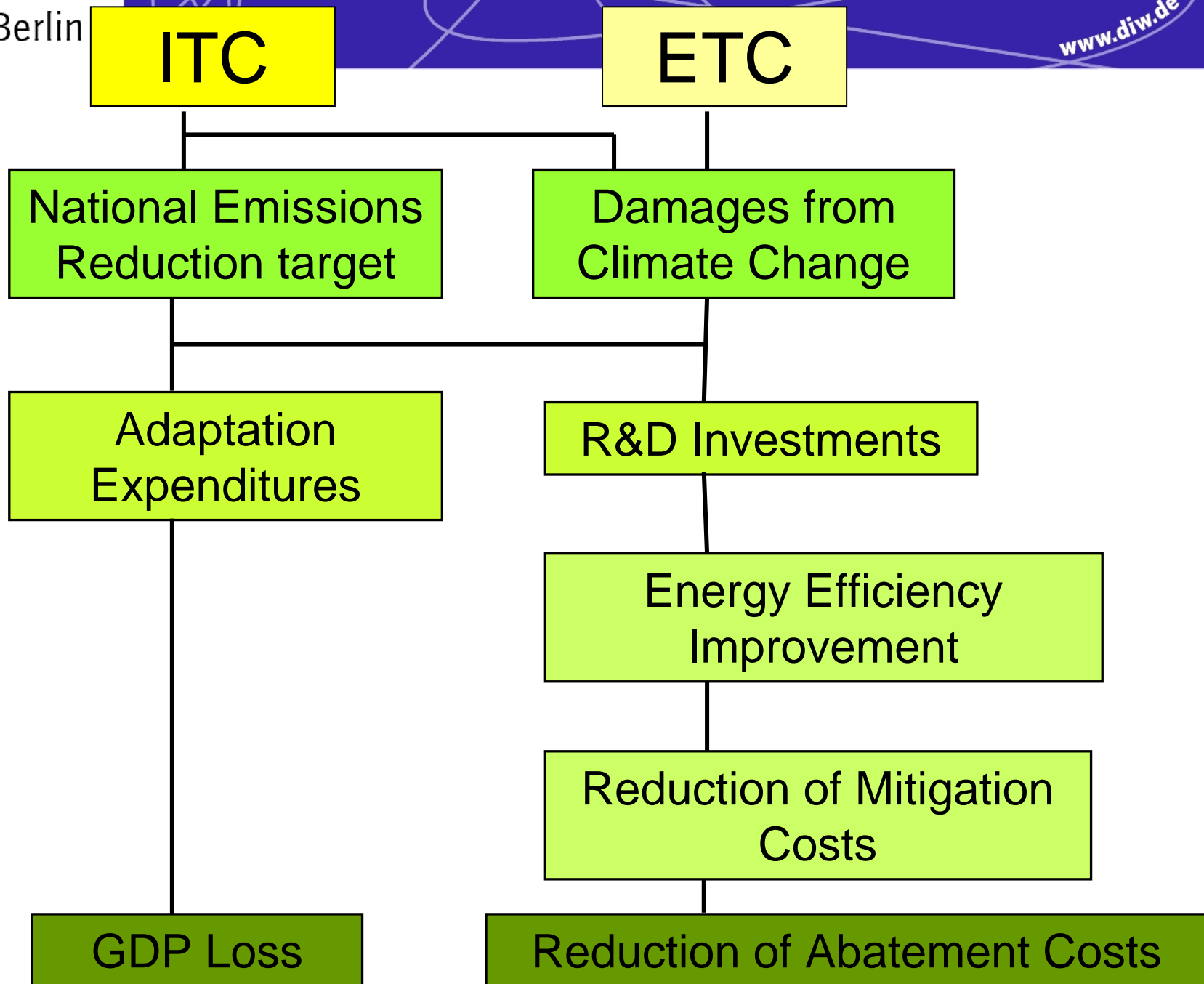
- Intertemporal CGE
- 100 years horizon, 5-yearly intervals
- 25 regions aggregated into 11 for this study
- 14 sectors (including 5 energy sectors)
- Induced technical change with respect to energy efficiency
- GHGs: CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HFC, PFC, SF<sub>6</sub>

# WIAGEM: regions

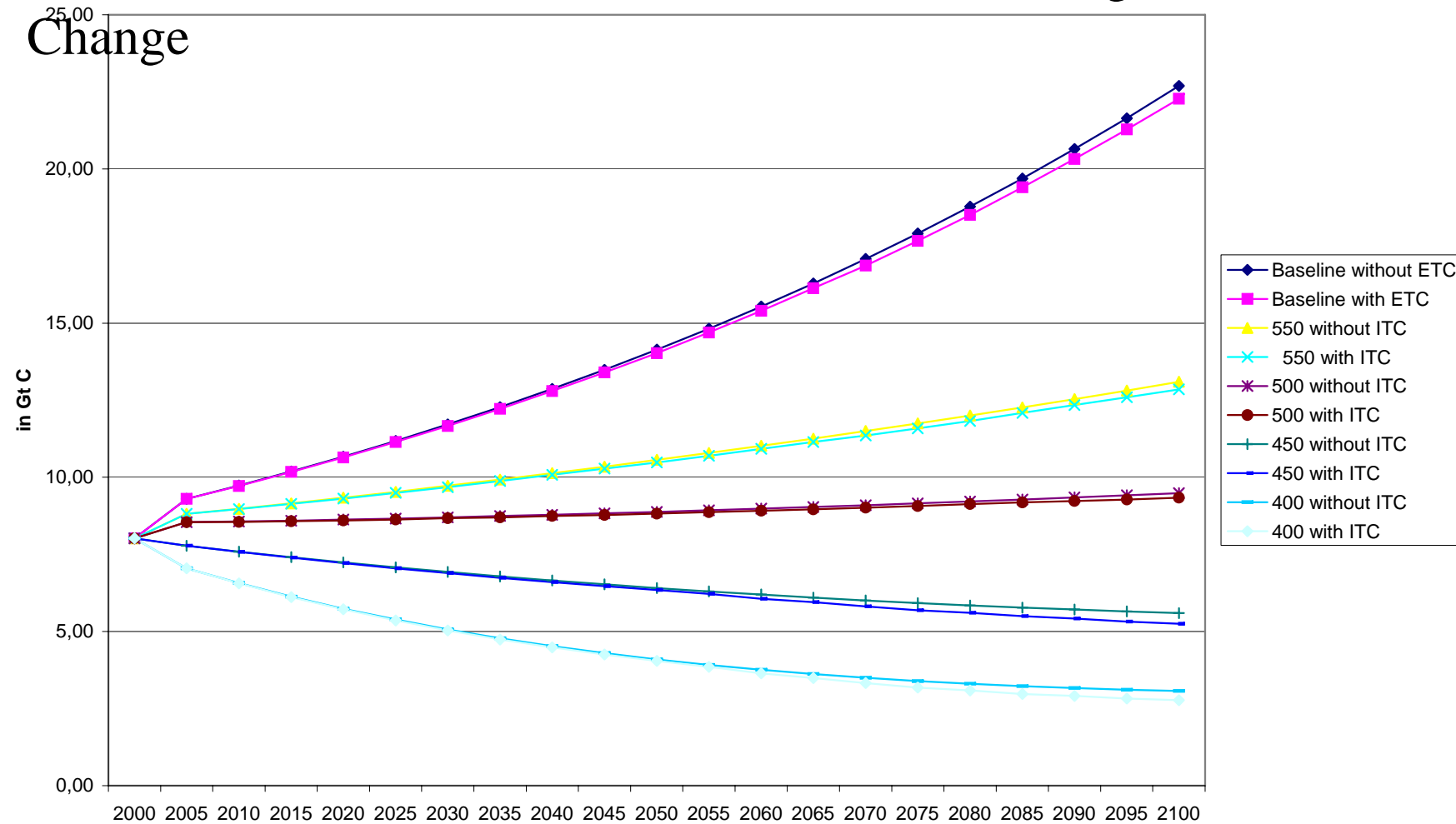
ASIA:	India and other Asian countries
CHN:	China
CAN:	Canada, New Zealand, and Australia
EU15:	European Union
JPN:	Japan
LSA:	Latin America
MEX:	Mexico
MIDE:	Middle East and North Africa
REC:	Russia, Eastern and Central European Countries
ROW:	Rest of the World
SSA:	Sub Saharan Africa
USA:	United States of America

# WIAGEM: sectors

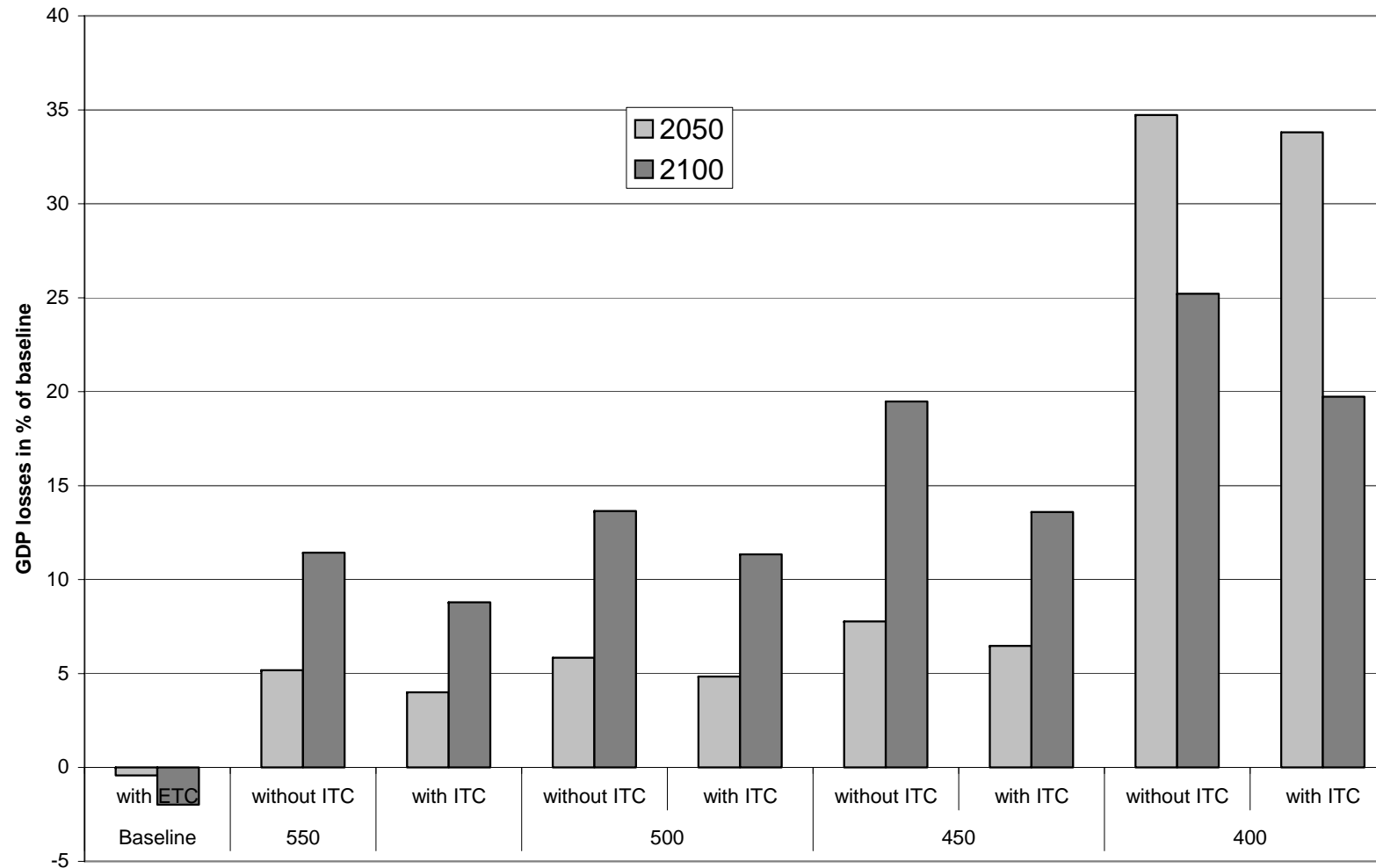
AGR:	Agriculture
COL:	Coal
CRP:	Chemical rubber and plastics
CRU:	Crude oil
EGW:	Electricity
GAS:	Natural gas
NFM:	Nonferrous metals
NMM:	Nonmetal mineral products
OIL:	Petroleum and coal products
OMS:	Other manufactures and services
ORE:	Iron and steel
PPP:	Pulp and paper
TRN:	Transport industries



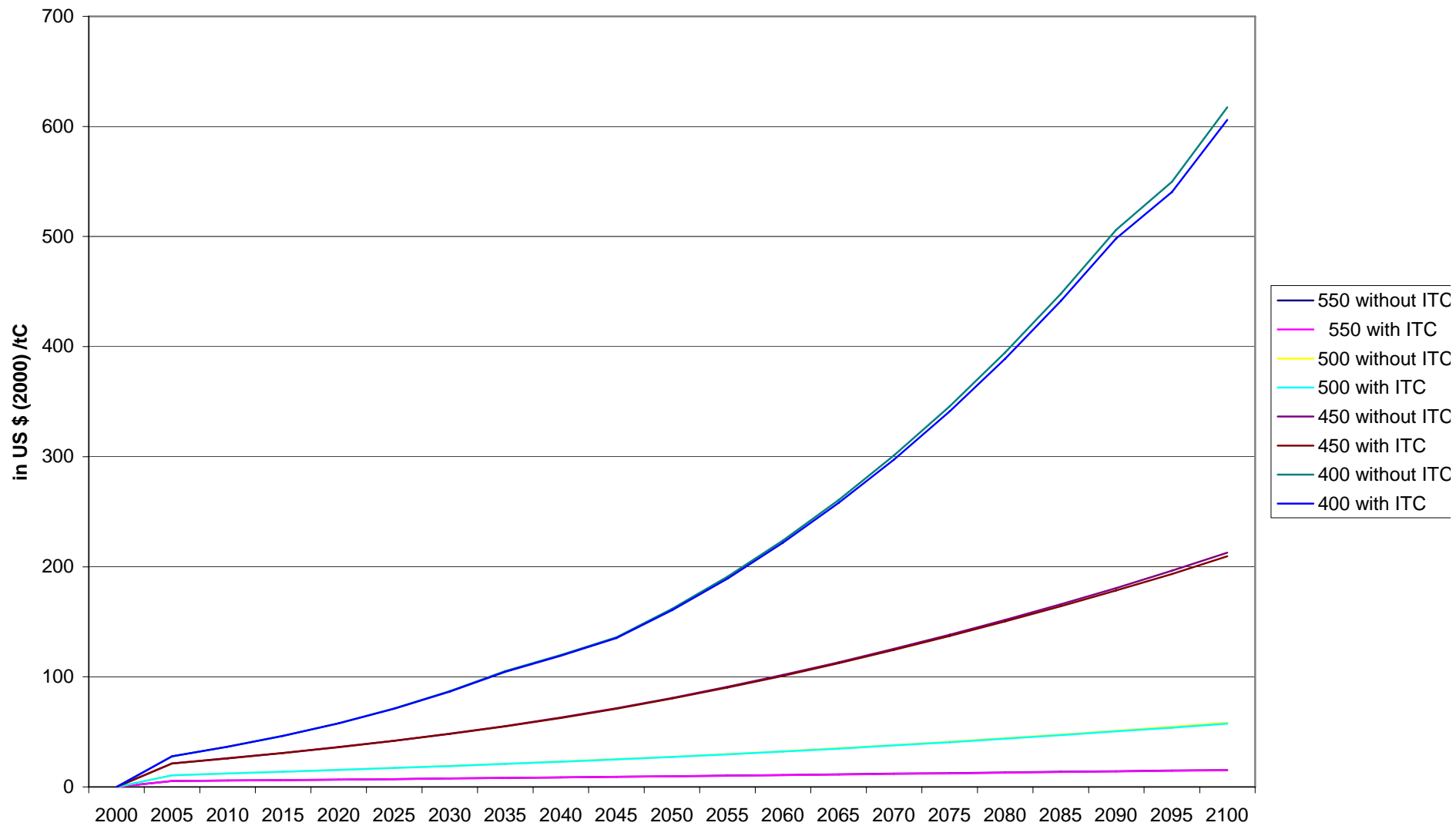
# Carbon Dioxide Concentrations under Different Emissions Stabilization Scenarios with and without Technological Change



## GDP Losses under Different Emissions Stabilization Scenarios

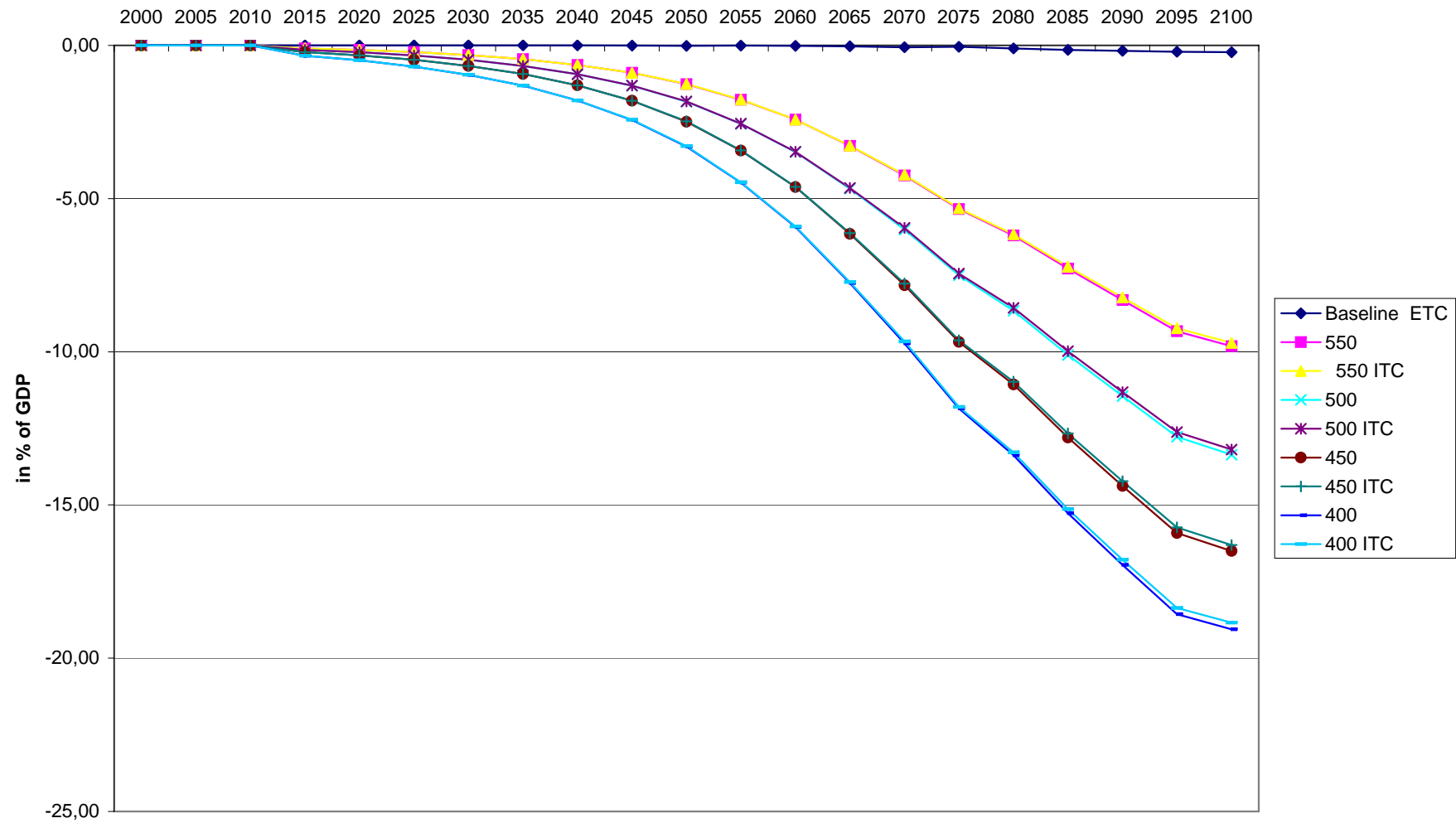


# Permit Prices under Different Emissions Stabilization Scenarios





# Avoided Damage compared with Baseline



## What do we mean by Technological Change, or Technological Progress?

Atkinson and Stiglitz (1969): "...The recent literature on technological progress has almost entirely been based on the assumption that its effect can be represented as shifting the production function outwards.... this approach seem, however, to have forgotten the origins of the neo-classical production function: as the number of production processes increases (in an activity analysis model), the production possibilities can be more and more closely approximated by a smooth, differentiable curve. But the different points on the curve still represent different processes of production, and associated with each of these processes there will be certain technical knowledge specific to that technique.

## What do we mean by Technological Change, or Technological Progress?

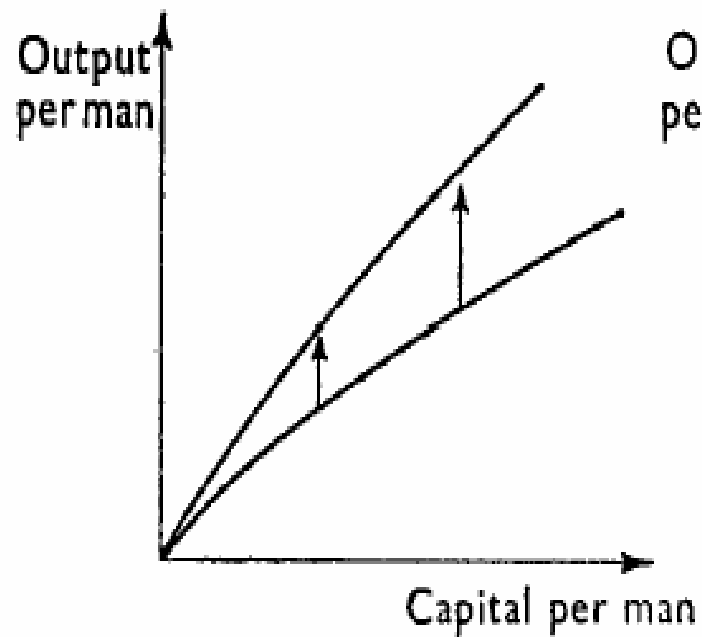


FIG. 1.

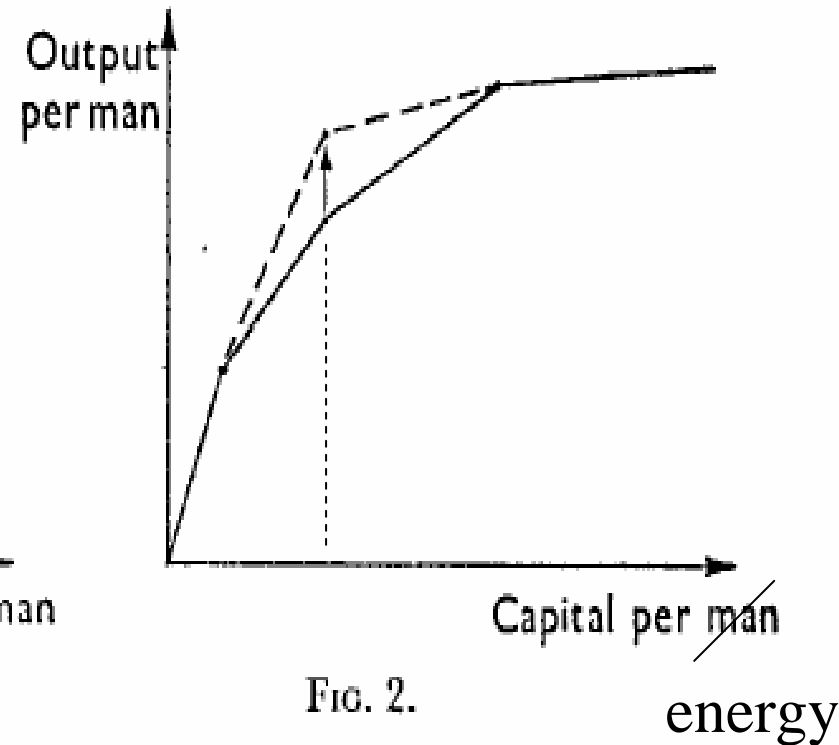
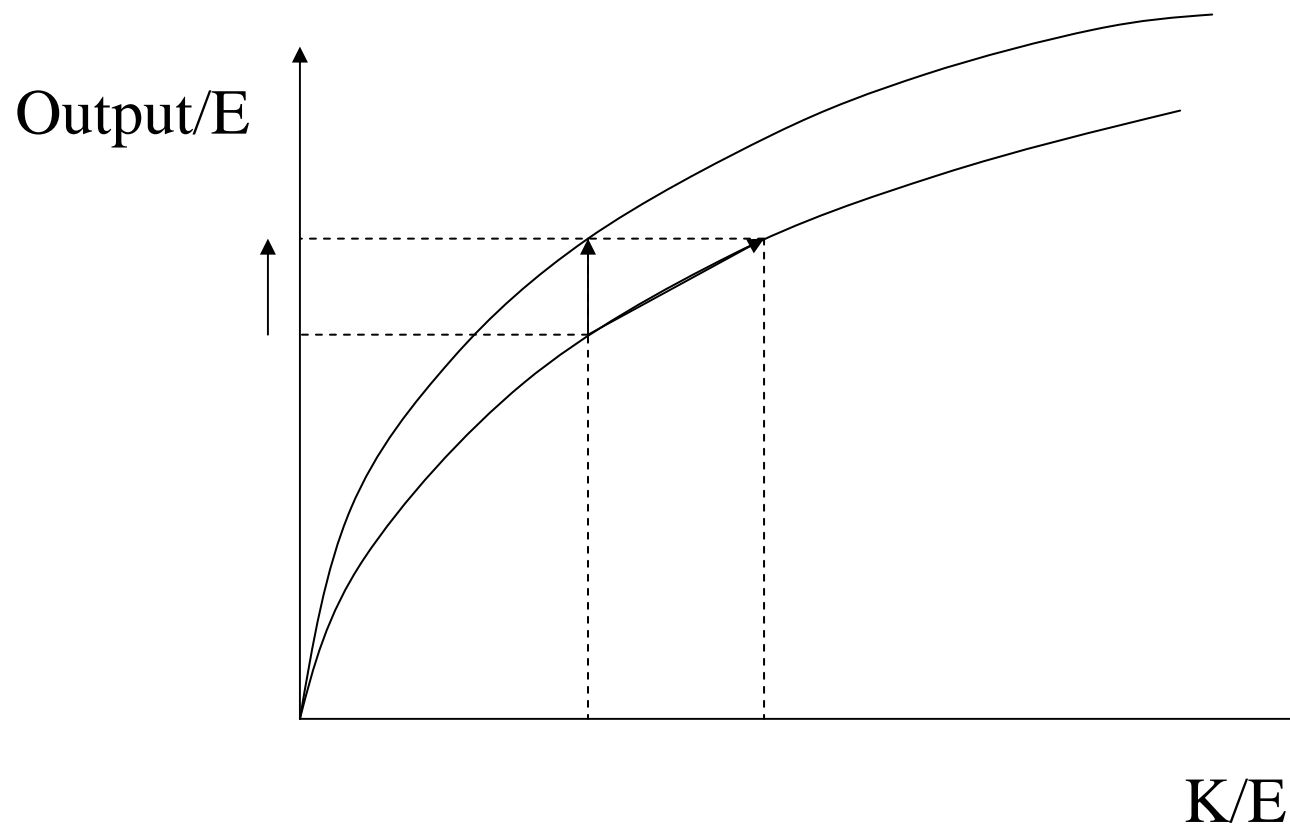


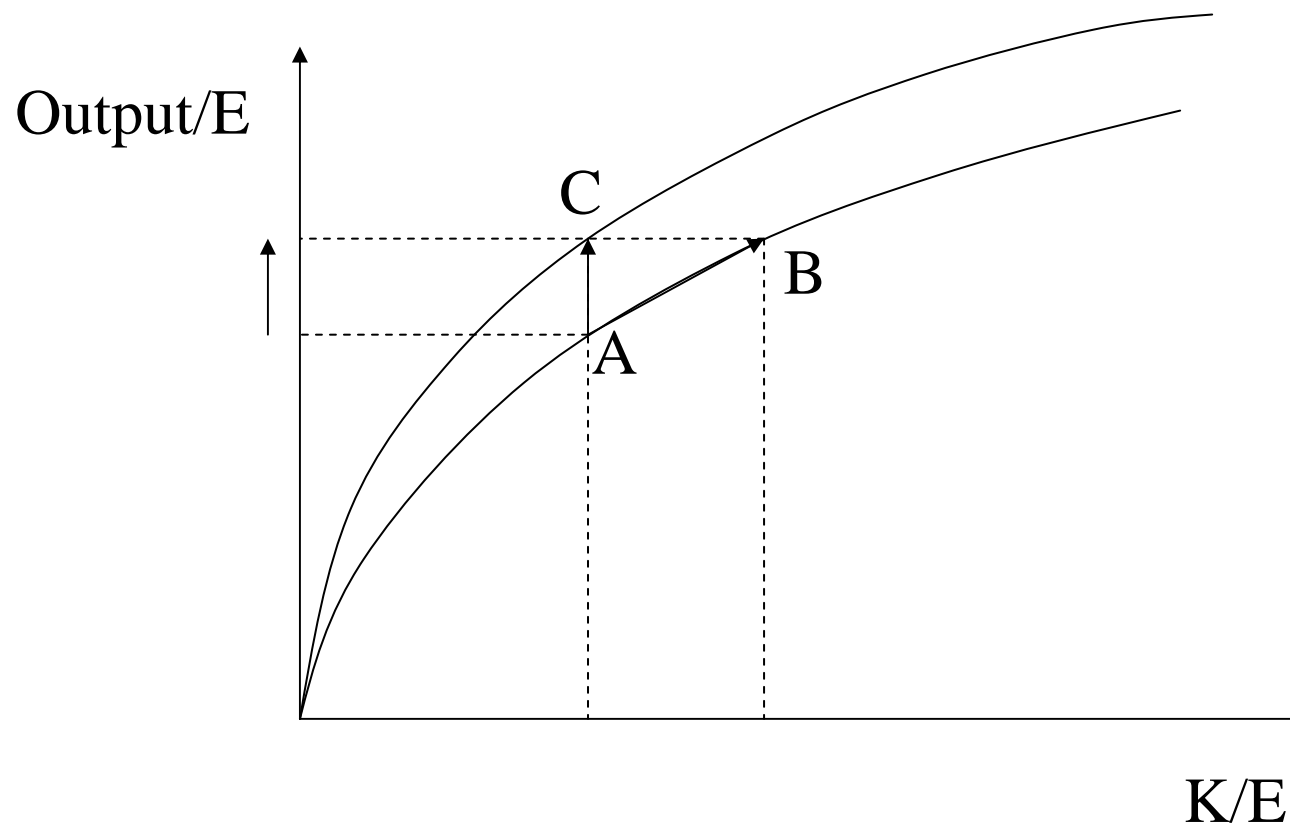
FIG. 2.

energy

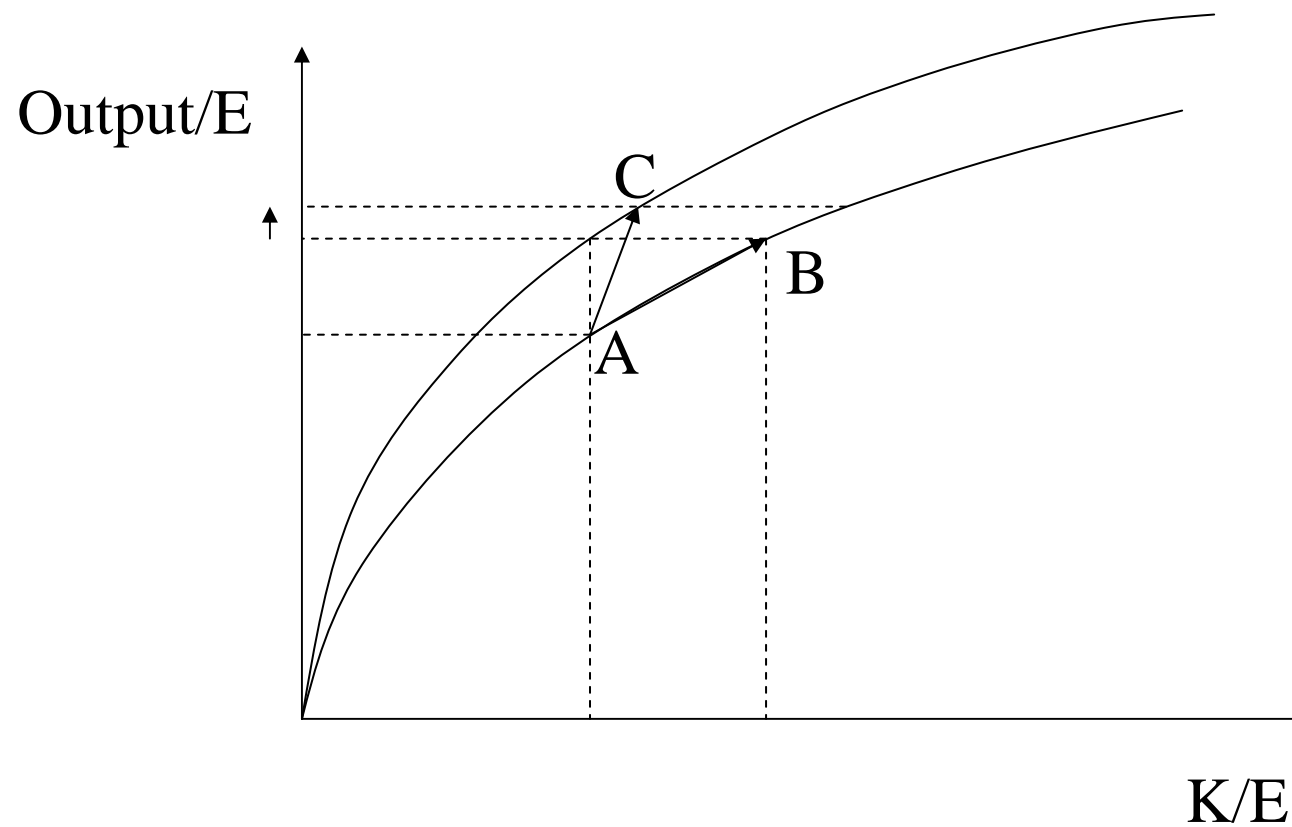
## What do we mean by Technological Change, or Technological Progress?



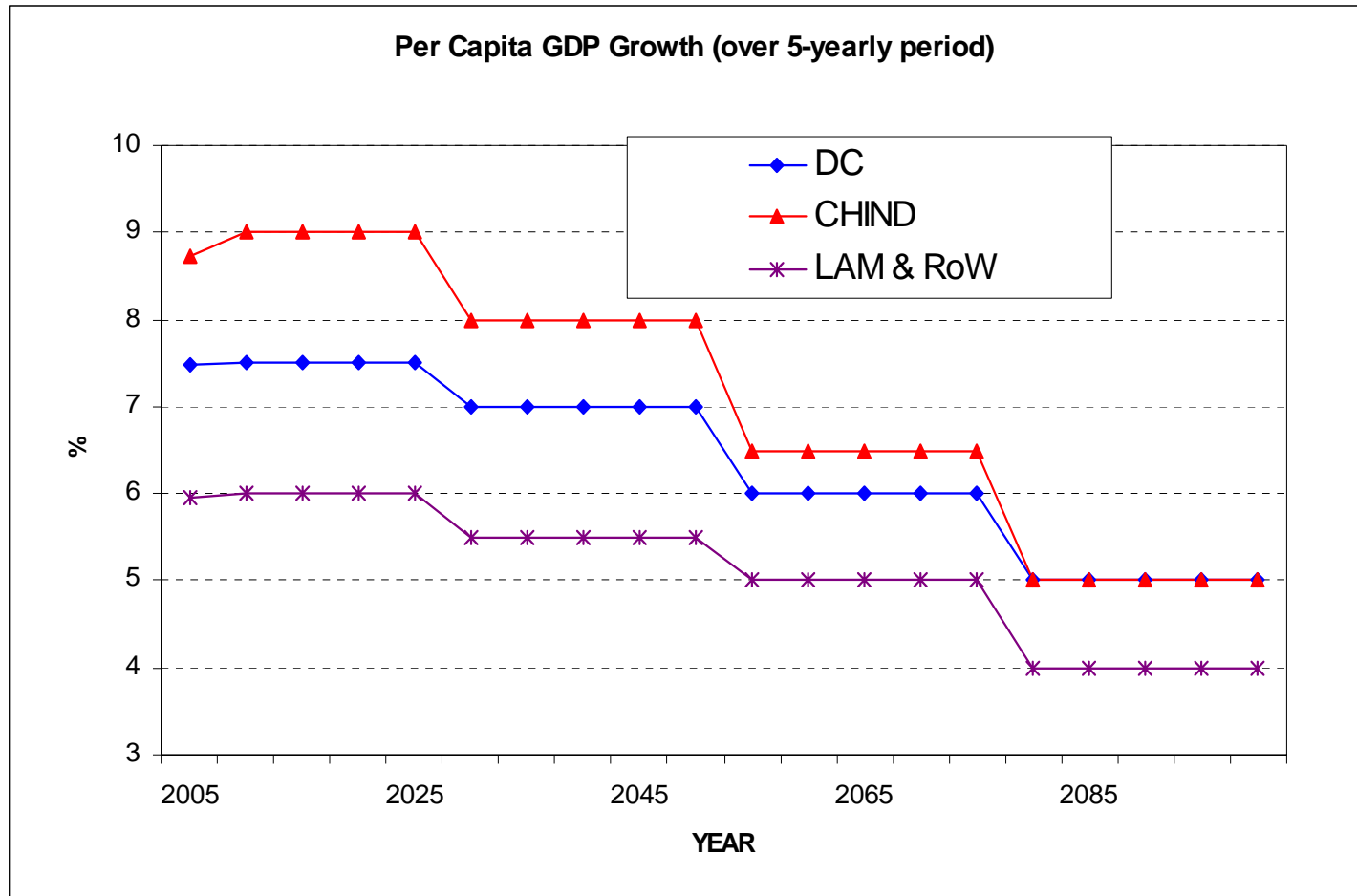
## What do we mean by Technological Change, or Technological Progress?



## What do we mean by Technological Change, or Technological Progress?



# Per capita GDP growth (over 5-year)

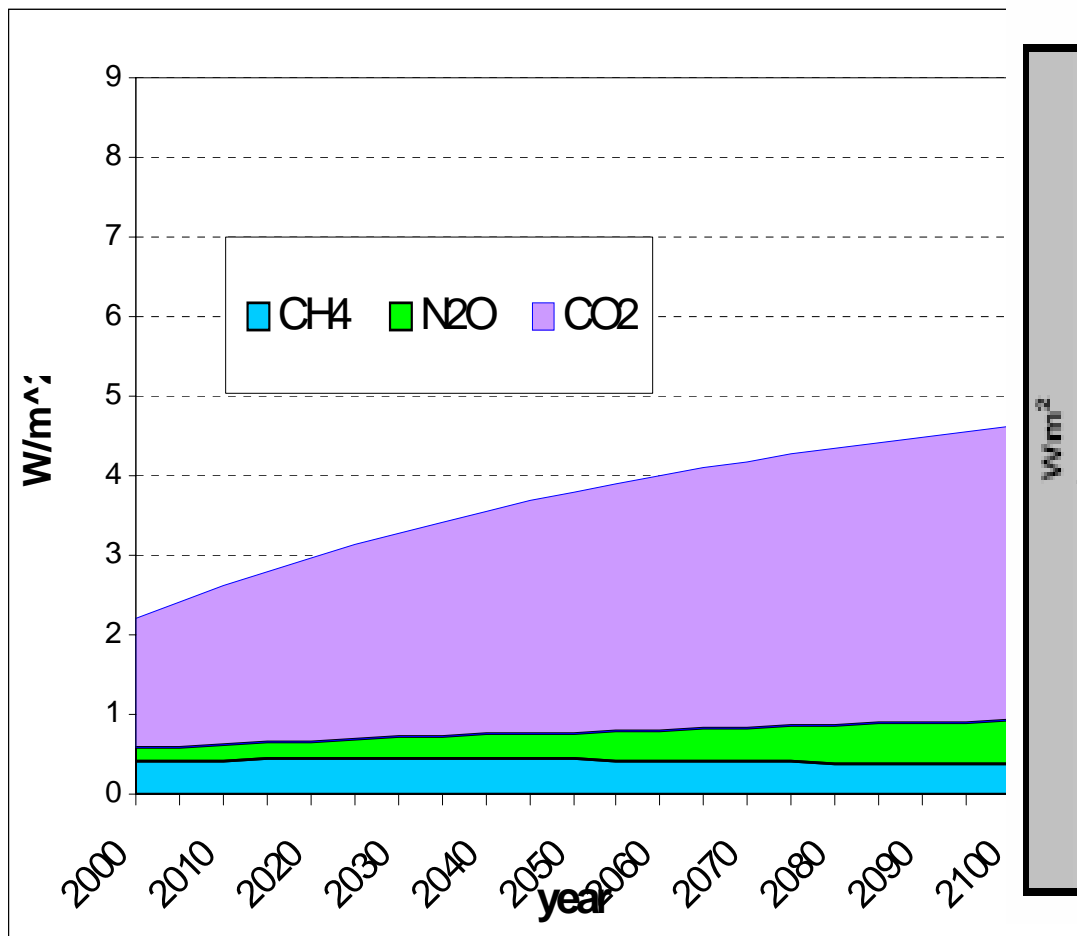




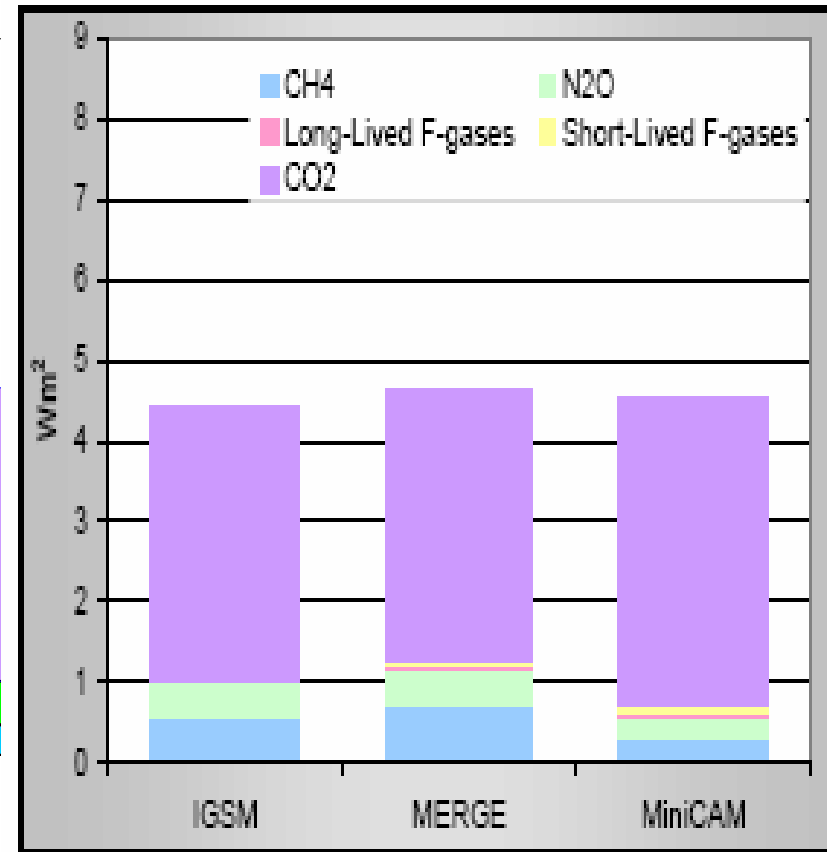
# Level 2 Scenario Results



# Radiative Forcing



## Level 2 Scenarios



Growth rate of K – Growth rate of E = Growth rate of K/E ratio

electricity	2005	2010	2015	2020	2025	2030	2035	2040	2045
USA	1.2	3.7	5.6	6.8	7.5	7.4	7.4	7.3	7.1
EU15	0.7	2.2	3.4	4.3	5.0	5.2	5.5	5.6	5.7
JPN	0.3	1.0	1.7	2.3	2.8	3.1	3.4	3.6	3.8

Equivalent rate of “Technological Progress” to keep K/E constant and yet achieving the same OUTPUT growth:

electricity	2005	2010	2015	2020	2025	2030	2035	2040	2045
USA	3.8	10.1	14.7	18.7	22.6	24.1	27.0	29.5	21.3
EU15	1.8	5.0	7.4	9.3	10.8	11.8	12.6	12.9	6.9
JPN	0.5	2.1	3.7	5.0	6.1	7.3	8.1	8.8	7.6