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GHG Emission Reduction Potential in Industrial Sector-cement industry in Korea

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- energy consumption and GHG emissions
- model
- potential for energy efficiency and GHG emission reduction
- MAC and policy instruments
- conclusion

introduction

- GHG emission reduction and energy efficiency in Korean cement industry
  - ∘ using MARKAL
- marginal abatement cost of GHG
- cost effectiveness of policy instruments

energy consumption and GHG emission

- cement supply & demand

- cement consumption increase 3.1% per annum since 1991
  - development of new town and infrastructure
  - rapid growth of slag cement production

	1991	1995	2000	2003	2004	increase ('91-'04)
production	38,335	55,130	51,255	59,194	54,330	2.7%
-slag cement	1,710 (4.5%)	3,609 (6.5%)	5,074 (9.9%)	7,847 (13.3%)	8,736 (16.1%)	13.4%
-clinker	34,999	51,894	45,719	51,575	48,251	2.5%
export	1,228	966	3,945	2,612	2,641	9.6%
import	7,160	2,082	518	1,809	3,398	9.4%
consumption	37,115	56,502	48,000	58,302	54,942	3.1%

energy consumption and GHG emission

- energy consumption

- growth of energy consumption (2.8% in 1990-2003)
  - decrease of heavy oil, increase of bituminous coal and electricity
  - main energy of bituminous coal (86%)

	1990	1995	2000	2003	growth ('90-'03)
B-C	67 (2.4%)	22 0 (4.9%)	41 (1.1%)	29 (0.7%)	-6.24%
bituminous coal	2,450 (86.5%)	3,797 (83.7%)	3,175 (86.1%)	3,502 (86.3%)	2.79%
electricity	314 (11.1%)	521 (11.5%)	471 (12.8%)	527 (13.0%)	4.06%
Sum (1,000 TOE)	2,831	4,538	3,687	4,058	2.81%

energy consumption and GHG emission

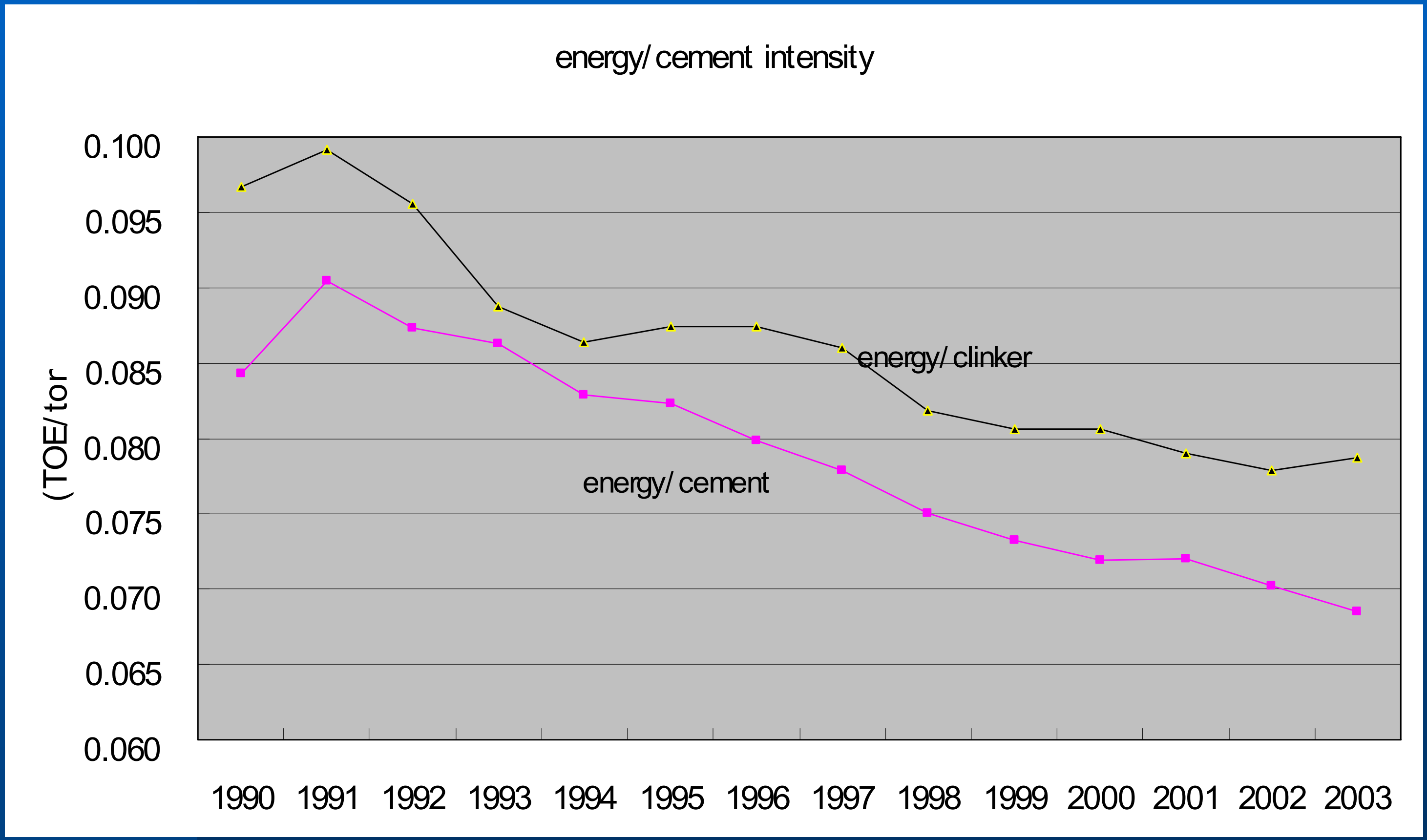
- cement supply & demand

- improvement of energy efficiency per cement production
  - decrease of energy consumption per cement produced (TOE/ton) (0.084 in 1990 to 0.069 in 2003)
  - decrease of energy/clinker intensity (from 0.097 to 0.079)

- efficiency improvement due to energy conservation investment
  - adoption of new technologies (NSP, roller mill etc.)

energy consumption and GHG emission

- energy/cement intensity



energy consumption and GHG emission

- GHG emission from fuel combustion

- increase of GHG emission from electricity consumption
  - construction of coal-fired power plant
  - increase of emission factor of power production (1.273TC/TOE in 1990 to 1.744 in 1997)

	1990	1995	2000	2003	growth ('90-'03)
B-C	59 (1.9)	193 (3.8)	36 (0.9)	26 (0.6)	-6.1%
bituminous	2,595 (85.0)	4,021 (79.7)	3,362 (80.8)	3,708 (81.1)	2.8%
electricity	399 (13.1)	832 (16.5)	764 (18.4)	836 (18.3)	5.9%
Sum (1,000TC)	3,053	5,045	4,162	4,570	3.2%

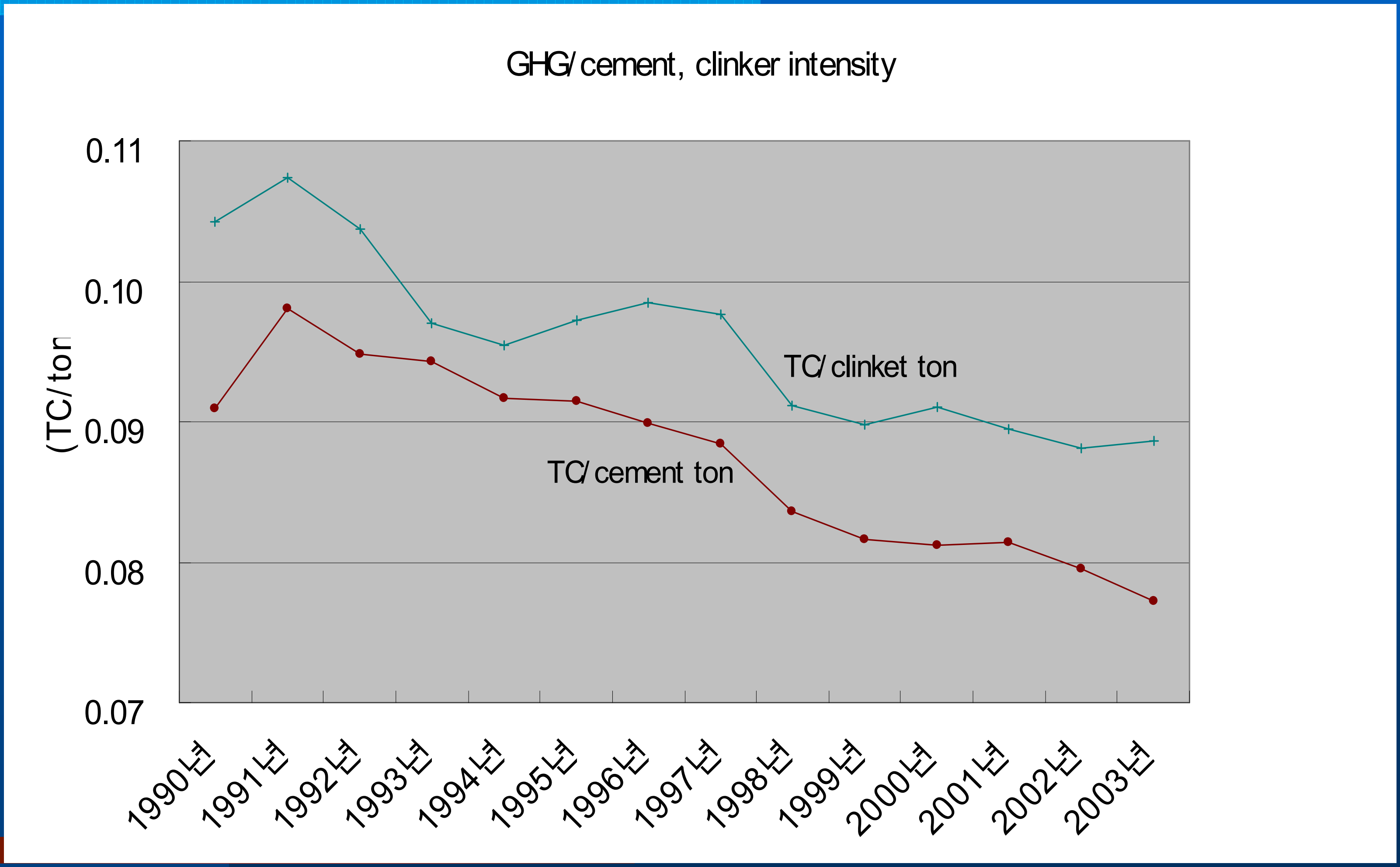
energy consumption and GHG emission

- GHG intensity

- improvement of GHG intensity
  - decrease of GHG/cement (TC/ton)(0.091 in 1990 to 0.077 in 2003)
  - decrease of GHG/clinker (TC/ton)(0.104 in 1990 to 0.089 in 2003)

energy consumption and GHG emission

- GHG intensity



energy consumption and GHG emission

- total GHG emission

- GHG from calcination is more than GHG from fuel combustion
  - share of calcination is 61% in 2003
  - GHG from calcination increase faster than GHG from fuel combustion

	1990	1995	2000	2003	growth ('90-'03)
B-C	59	193	36	26	-6.11
bituminous	2,595	4,021	3,362	3,708	2.78
electricity	399	832	764	836	5.85
fuel combustion	3,053	5,045	4,162	4,570	3.15
calcination	4,047	7,173	6,319	7,129	4.45
Total GHG (1,000TC)	7,100	12,218	10,482	11,699	3.92

model

- MARKAL
  - ◦ least-cost energy system s.t constraints
  - ◦ objective function (cost function : investment, O&M cost etc.)
  - ◦ constraints (demand & supply, emission, etc.)
  - ◦ decision variable (energy supply, technology activity & investment etc.)
- study period : 40 years (2001-2041)
  - ◦ isolated industry
  - ◦ discount rate (7%), constant value in 2001 ($1=1,326 won)

model

- Reference Energy System (RES)
  - energy service demand (cement production)
  - commodity (energy, material, emission, etc.)
  - energy source (import including electricity)
  - technology (resource, process)

model

- cement production is 71,742 thousand tons in 2041
  - share of blended (slag) cement is 15% in 2041

	2001	2006	2011	2016	2021	2026	2031	2036	2041
Cement production	58,040	59,593	64,322	68,725	70,266	70,869	71,477	72,086	72,695
- Portland cement	51,250	51,846	55,317	59,104	59,726	60,239	61,020	61,273	61,791
- slag cement	6,790	7,747	9,005	9,622	10,540	10,630	10,722	10,813	10,904

model

- scenarios
  - baseline (10% of current technology remains in 2021)
  - 5 new technologies (2 for calcination, 3 for grinding)
  - increased share of slag cement (20% from 2021)
  - substitution of bituminous coal (30%) by waste tyre
  - carbon tax ($300/TC from 2011)
  - energy tax ($300/TOE from 2011)
  - fuel price increase (twice for bit. coal, electricity, B-C from 2011)

potential for energy and GHG

- potential for energy efficiency

- energy demand increase 0.5% per annum in 2001-2041
  - energy demand is 205.2PJ (4,925 ths.TOE) in 2041
  - demand for bit.coal (0.5%) is faster than electricity (0.2%)
  - bituminous coal is main fuel

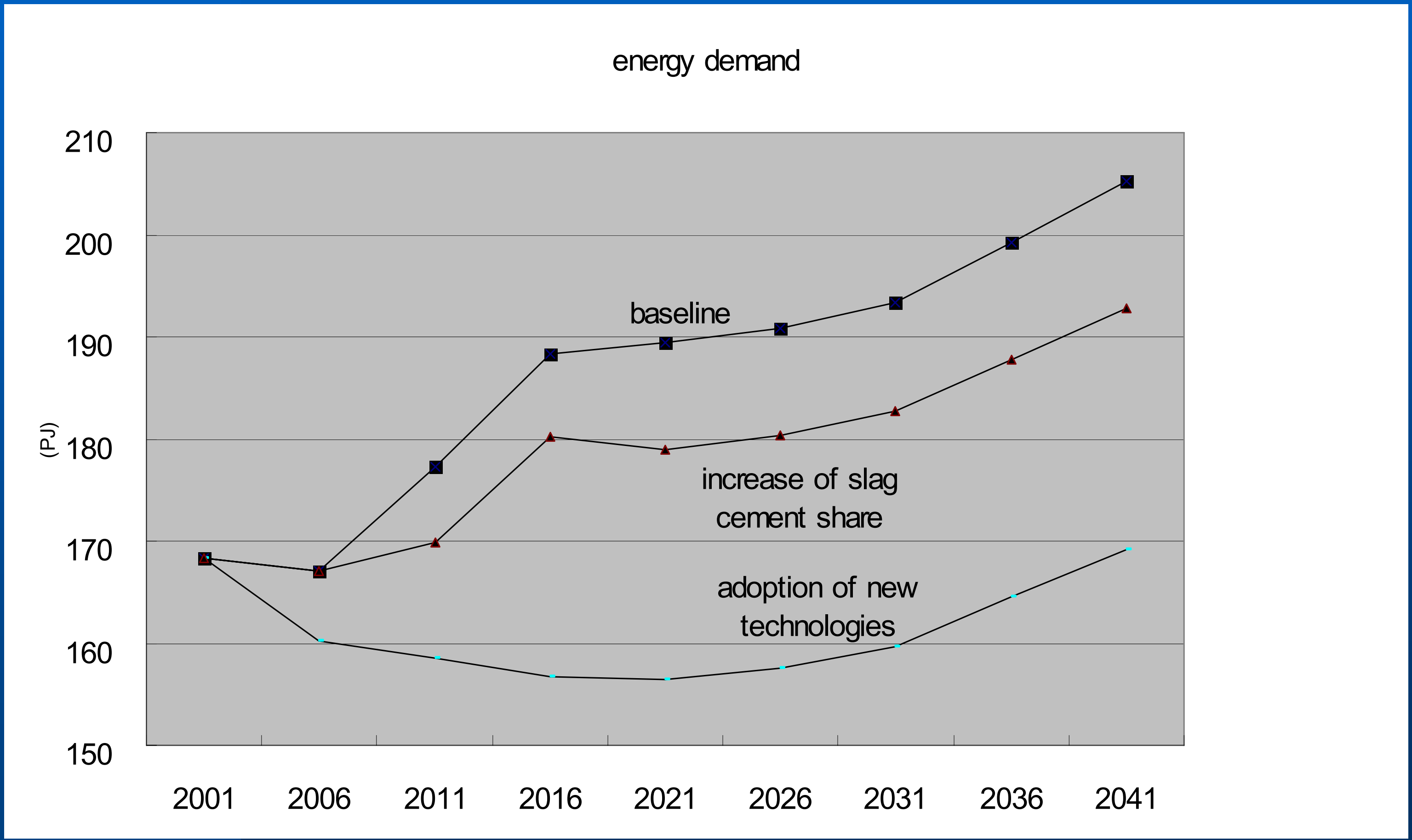
potential for energy and GHG

- potential for energy efficiency

- energy efficiency is highest for new technology scenario
  - energy consumption of new technology (solar lime kiln, advanced burner tip for kiln) is 16.5% lower than baseline
  - energy saving is 6% for slag cement
  - low efficiency improvement for carbon tax and energy tax (0.1%)
  - low improvement for electricity increase (0.1%)
  - no reduction in energy consumption for coal and oil price increase

potential for energy and GHG

- potential for energy efficiency



potential for energy and GHG

- potential for energy efficiency

- energy savings of economic instruments is lower than tech. instruments
- economic instruments encourage adoption of new technologies
  - carbon tax, energy tax, fuel price increase can accelerate adoption of new technologies
  - energy efficiency increase 1.9% more than new technologies (combination of economic- and technology instruments)

potential for energy and GHG

- potential for GHG emission reduction

- GHG emission increase 0.54% in 2001-2041 (13,030 ths.TC in 2041)
  - share of GHG from calcination increase to 58.4% in 2041
  - GHG excluding electricity consumption is 6.9-8.0% lower than baseline

	2001	2006	2011	2016	2021	2026	2031	2036	2041
baseline(1,000 TC)	10,490	10,521	11,194	11,921	12,019	12,119	12,278	12,649	13,030
-calcination	6,021	6,091	6,499	6,944	7,017	7,077	7,168	7,386	7,610
(share)	57.4%	57.9%	58.1%	58.2%	58.4%	58.4%	58.4%	58.4%	58.4%
electricity consumption	834	811	833	850	838	842	856	882	905
(effect)	-8.0%	-7.7%	-7.4%	-7.1%	-7.0%	-6.9%	-7.0%	-7.0%	-6.9%

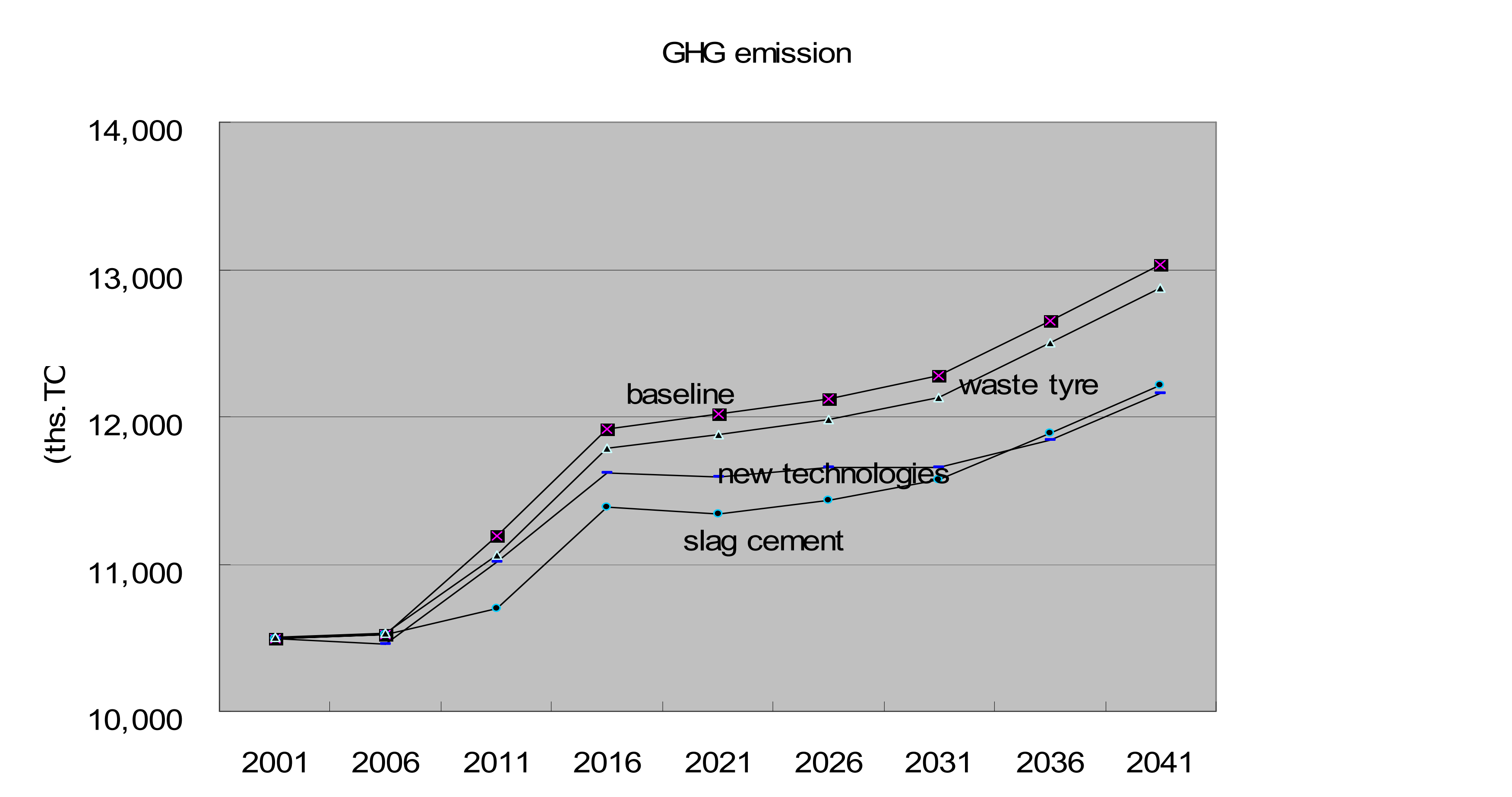
potential for energy and GHG

- potential for GHG reduction

- GHG emission reduction potential is highest for new technologies
  - 6.9% potential of GHG reduction for new technologies
  - 6.3% potential for slag cement
  - 1.2% potential for substitution of bituminous coal (30%) by waste tyre
  - low GHG reduction for carbon tax and energy tax (0.01%)
  - low potential for electricity price increase (0.02%)
  - no potential for coal and oil price increase

potential for energy and GHG

- potential for GHG reduction



potential for energy and GHG

- potential for GHG reduction

- low potential in GHG reduction for economic instruments
  - high potential for technology instruments

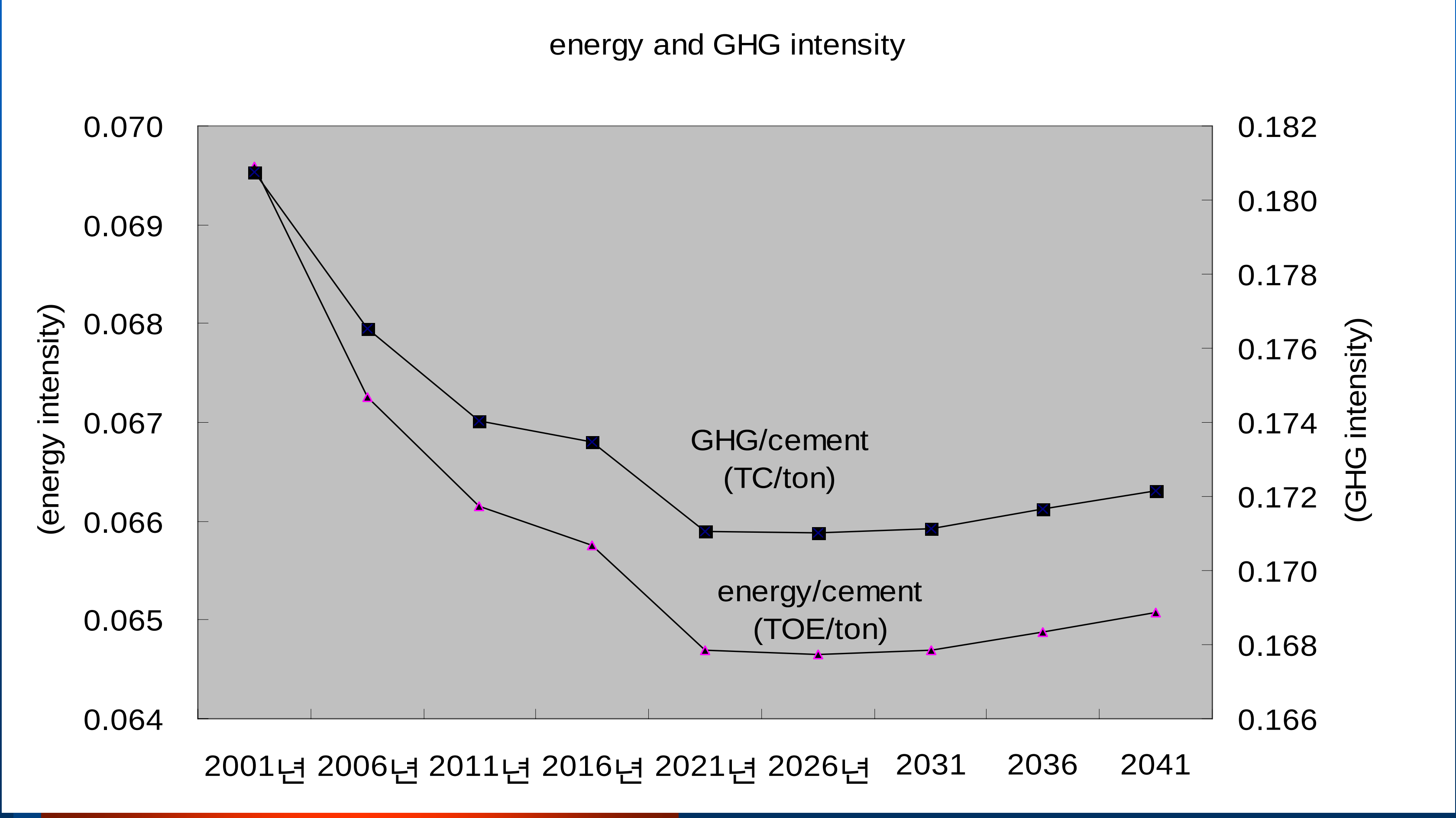
potential for energy and GHG

- energy and GHG intensity

- energy efficiency (energy/cement) improve 6.5% in 2041
  - efficiency decrease from 0.069 TOE/ton in 2001 to 0.065 in 2041
- GHG/cement intensity improve 3.1% in 2041
  - intensity decrease 0.181 (TC/ton) in 2001 to 0.171 in 2041
  - intensity for fuel combustion decrease 0.077 in 2001 to 0.072 in 2041

potential for energy and GHG

- energy and GHG intensity



MAC and policy instruments

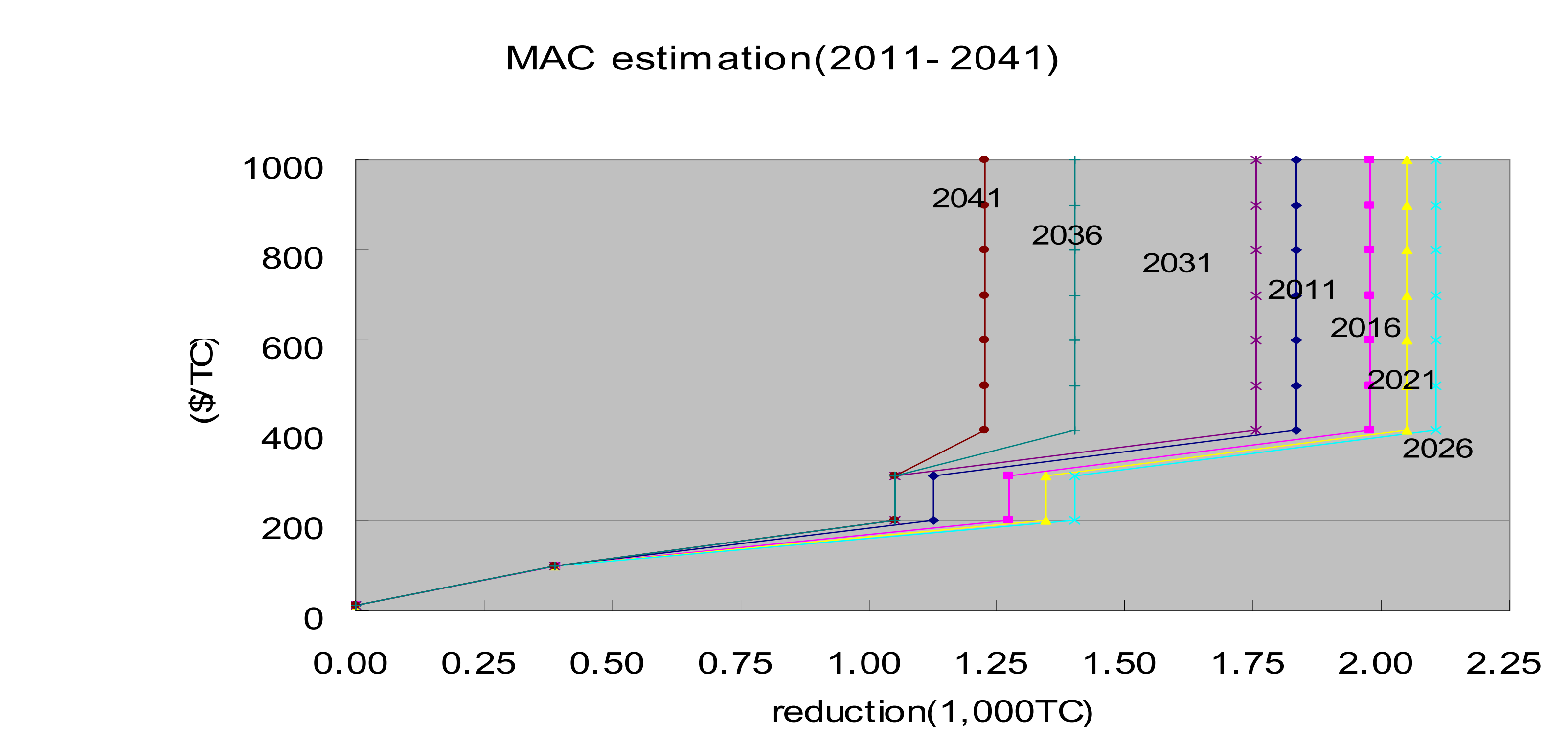
- MAC estimation

- MAC estimation for baseline
- estimation methods
  - carbon tax, cap constraint on emission

MAC and policy instruments

- MAC estimation

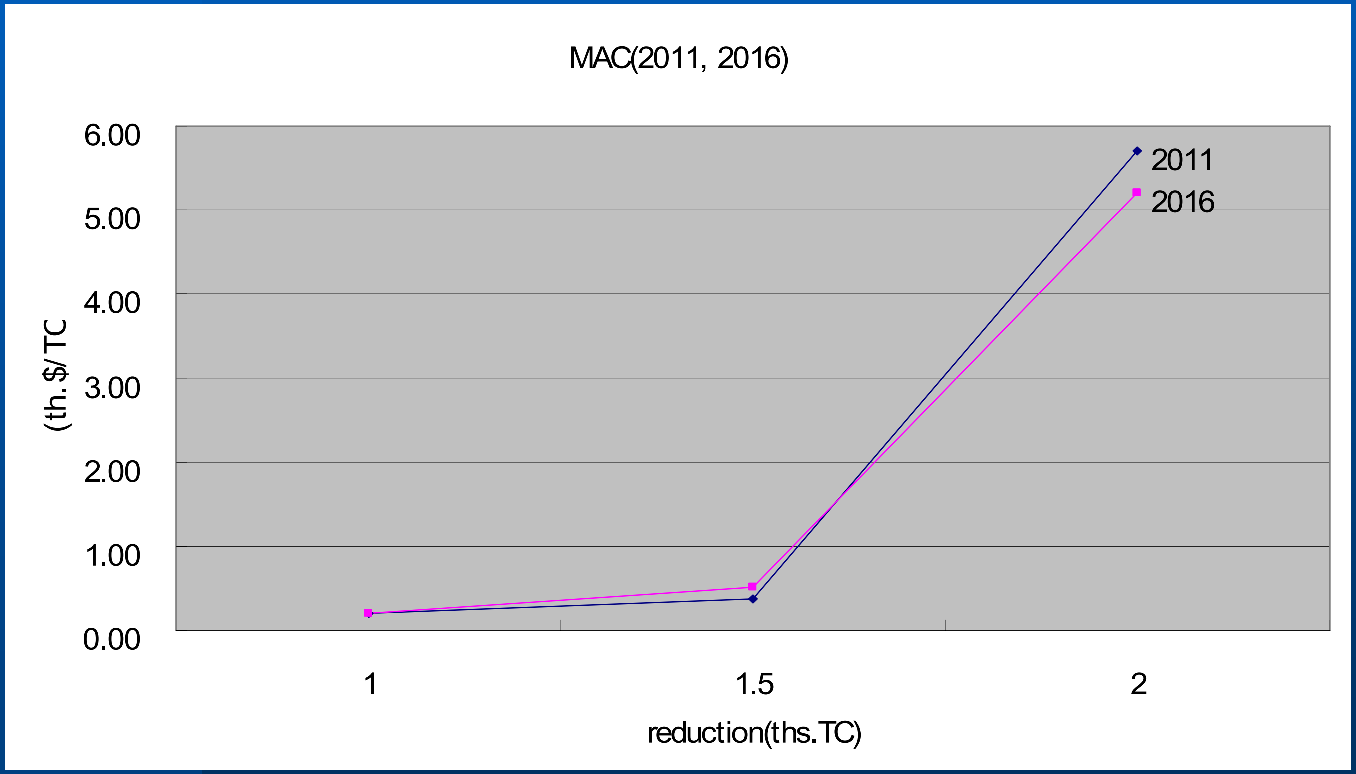
- MAC is $200-$300/TC by carbon tax method
  - MAC increase after 2026



MAC and policy instruments

- MAC estimation

- shadow price of emission is $200/TC by cap constraint



MAC and policy instruments

- MAC estimation

- shadow price of emission by cap constraint

cap constraint (1,000TC)	2011	2016	2021	2026	2031	2036	2041
1.0	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1.5	0.38	0.52	0.20	0.38	0.38	2.32	2.32
2.0	5.71	5.20	0.20	0.38	2.32	2.32	2.32
2.5	5.71	5.20	0.20	0.38	2.32	2.32	2.32
3.0	5.71	5.20	0.20	0.38	2.32	2.32	2.32

MAC and policy instruments

- MAC estimation

- MAC in Korea cement industry is $200/TC
  - ∘ high marginal cost
  - ∘ sharp increase after $400/TC

MAC and policy instruments

- policy instruments

- arbitrary reduction target
  - 0.01% reduction compared with baseline
- evaluation of cost-effectiveness for scenarios
  - based on MAC
- estimation of MAC for each scenario

MAC and policy instruments

- policy instruments

- negative MAC for new technologies and waste tyre
  - MAC for waste tire is -$190/TC
  - MAC for new technologies is -$40.2/TC

MAC and policy instruments

- policy instruments

- highest MAC for carbon tax
  - MAC for slag cement is \$3.37/TC
  - MAC is \$300/TC for carbon tax
  - \$266/TC for energy tax, \$237/TC for electricity price

- priority is waste tyre, new technologies, slag cement, energy tax, carbon tax

MAC and policy instruments

- policy instruments

scenarios	Instruments	MAC and total cost (2011-2041)		
		MAC	total cost	cost change
baseline	-		10,848	
- new technologies	adoption of new technologies	-$40.2/TC	10,847.66	-0.34
- slag cement	share increase of slag cement	$3.37/TC	10,848.03	+0.03
- waste tyre	substitution of bitu. coal by waste tyre (30%)	-$190/TC	10,846.38	-1.62
- carbon tax	imposition of carbon tax	$300/TC	17,443	+6,595
- energy tax	imposition of energy tax	$266/TC	13,228	+2,380
- electricity price	price increase	$237/TC	11,515	+667
- oil price	n.a	n.a	n.a	n.a
- coal price	n.a	n.a	n.a	n.a

conclusion

- low potential in energy efficiency and GHG reduction
  for economic instruments
  - non-inclusion of price signal effect for economic instruments
    (limited new technologies)
- role of government
  - barrier removal for new technologies
  - incentive or regulation, if necessary
  - develop new rule for slag cement use

Thank you

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