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Estimation of energy efficiency improvement opportunities for the cement industry in Taiwan

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Introduction

- **Taiwan's cement Sector**
  - Accounting for 3.5% of total industrial energy demand in 2014.
  - The second most energy-intensive sector in Taiwan.
  - Representing about 10% of total industrial CO_2 emissions in 2014.
- The Greenhouse Gas Reduction and Management Act specified a target for Taiwan's carbon emissions to be capped at 50% of the 2005 level by 2050.
- It is therefore essential to understand the energy efficiency improvement opportunities in Taiwan's cement industry.
- A bottom-up model is adopted for scenario analysis related to the availability of energy saving opportunities over the medium- and long-term (i.e., until 2035).
- The energy saving potentials for electricity and fuels are estimated in different technology diffusion scenarios, respectively.

Model (1/2)

- The process-specific bottom-up model (FORECAST-Industry) is applied in this study, and based on a three-level hierarchical structure.
- Industry is broken down into different sectors (e.g. cement sector).
- Each sector is further disaggregated into major production processes.
- EETs (Energy Efficient Technologies) are at the third level. EETs are defined as technologies that reduce the SEC of a particular process.

Sectors: Cement

Processes:

- Cement Grinding
  - 16. Roller press as pre-grinding to ball mill
  - 17. Adjustable speed drive for finish grinding
  - 18. Advanced grinding technology
- Clinker Calcination
  - 6. Process control and optimization in clinker making
  - 7. Combustion system improvement
  - 8. High temperature heat recovery for power generation
  - 9. Low temperature heat recovery for power generation
  - 10. Organic Rankine Cycle (ORC)
  - 11. Increasing number of preheater stages in kilns
  - 12. Efficient clinker cooler
  - 13. Fuel switch
  - 14. Adjustable speed drive for kiln fans
  - 15. Adjustable speed drive for clinker cooler fans
- Raw Materials and fuel preparation
  - 1. Roller press as pre-grinding to ball mill
  - 2. Vertical mill
  - 3. High-Efficiency Classifiers and Separators
  - 4. Efficient homogenization of materials
  - 5. Adjustable speed drive for raw mill fans

Energy Efficient Technologies

Model (2/2)

- The annual energy savings (ES) of an EET in year t for one scenario (Sc) are calculated according to the specific saving potential (sp), the diffusion (Diff) of the EET in year t and the industrial production (IP) of the related process (p).

$$ES_{t,p,EET,Sc} = sp_{EET} \times (Diff_{t,EET,Sc} - Diff_{t=baseyear,EET,Sc}) \times IP_{t,p}$$

- Energy saving potentials are assessed through the diffusion of EETs in different scenarios by varying the speed of technology diffusion.
- We distinguish three diffusion scenarios that lead to two categories of saving potentials calculated as difference to the frozen-efficiency scenario.
  - Frozen efficiency scenario: Assumes no further efficiency improvements, which is used as the baseline.
  - Business-as-usual (BAU) diffusion scenario : The technology diffusion is based on past development without promotion policies.
  - Technical diffusion scenario : Represents the development, if all technical saving options are implemented, without consideration of cost-effectiveness. It represents the upper limit for energy saving potentials.

Data (1/2)

Input data of specific energy savings

Process	Energy efficiency technology	Specific energy savings: Electricity (GJ/t)	Specific energy savings: Fuels (GJ/t)
Raw material preparation	1. Roller press as pre-grinding to ball mill	0.0294	0
	2. Vertical mill	0.0396	0
	3. High-Efficiency Classifiers and Separators	0.0183	0
	4. Efficient homogenization of materials	0.0096	0
	5. Adjustable speed drive for raw mill fans	0.0012	0
Clinker production	6. Process control and optimization in clinker making	0.0085	0.15
	7. Combustion system improvement	0	0.29
	8. High temperature heat recovery for power generation	0.1109	0
	9. Low temperature heat recovery for power generation	0.0799	0
	10. Organic Rankine Cycle (ORC)	0.03	0
	11. Increasing number of preheater stages in kilns	-0.003	0.079
	12. Efficient clinker cooler	-0.011	0.27
	13. Fuel switch	0	0
	14. Adjustable speed drive for kiln fans	0.0178	0
	15. Adjustable speed drive for clinker cooler fans	0.0004	0
Cement grinding	16. Roller press as pre-grinding to ball mill	0.0879	0
	17. Adjustable speed drive for finish grinding	0.0005	0
	18. Advanced grinding technology	0.07	0

Annual production output by process

Unit: million tons

Process	2013	2015	2020	2025	2030	2035
Raw material preparation	16.27	15.19	14.31	13.48	13.12	12.48
Clinker production	16.27	15.19	14.31	13.48	13.12	12.48
Cement grinding	15.16	14.20	13.50	12.97	12.74	12.23

Data (2/2)

Process	Energy efficiency technology	Diffusion rate (%)				
		Base year	BAU scenario		Technical scenario	
		2013	2020	2030	2020	2030
Raw material preparation	1. Roller press as pre-grinding to ball mill	19.0	19.0	26.0	23.0	33.5
	2. Vertical mill	43.1	49.0	49.0	49.0	56.0
	3. High-Efficiency Classifiers and Separators	56.9	69.8	69.8	69.8	89.2
	4. Efficient homogenization of materials	45.2	45.2	56.0	49.0	73.8
	5. Adjustable speed drive for raw mill fans	49.7	53.8	63.8	59.7	84.0
Clinker production	6. Process control and optimization in clinker making	69.8	69.8	69.8	77.8	89.2
	7. Combustion system improvement	28.9	34.9	44.9	40.9	59.4
	8. High temperature heat recovery for power generation	75.0	75.0	75.0	83.0	94.6
	9. Low temperature heat recovery for power generation	75.0	75.0	75.0	83.0	94.6
	10. Organic Rankine Cycle (ORC)	8.1	8.1	11.9	11.9	40.9
	11. Increasing number of preheater stages in kilns	5.4	5.4	9.2	9.2	22.1
	12. Efficient clinker cooler	75.0	79.0	86.1	83.0	94.6
	13. Fuel switch	11.6	11.6	25.4	22.0	46.8
	14. Adjustable speed drive for kiln fans	66.8	66.8	72.2	70.9	89.2
	15. Adjustable speed drive for clinker cooler fans	28.9	39.3	53.8	49.7	77.8
Cement grinding	16. Roller press as pre-grinding to ball mill	75.0	75.0	75.0	83.0	94.6
	17. Adjustable speed drive for finish grinding	49.7	53.8	63.8	59.7	84.0
	18. Advanced grinding technology	0.0	0.0	14.5	14.5	39.3

- The exogenous assumptions on technology diffusion for each efficiency technology are shown in above table.
- The future diffusion is obtained from the in-depth interviews with experienced engineers, technicians, and certified energy managers in all representative cement plants in Taiwan.

Results (1/2)

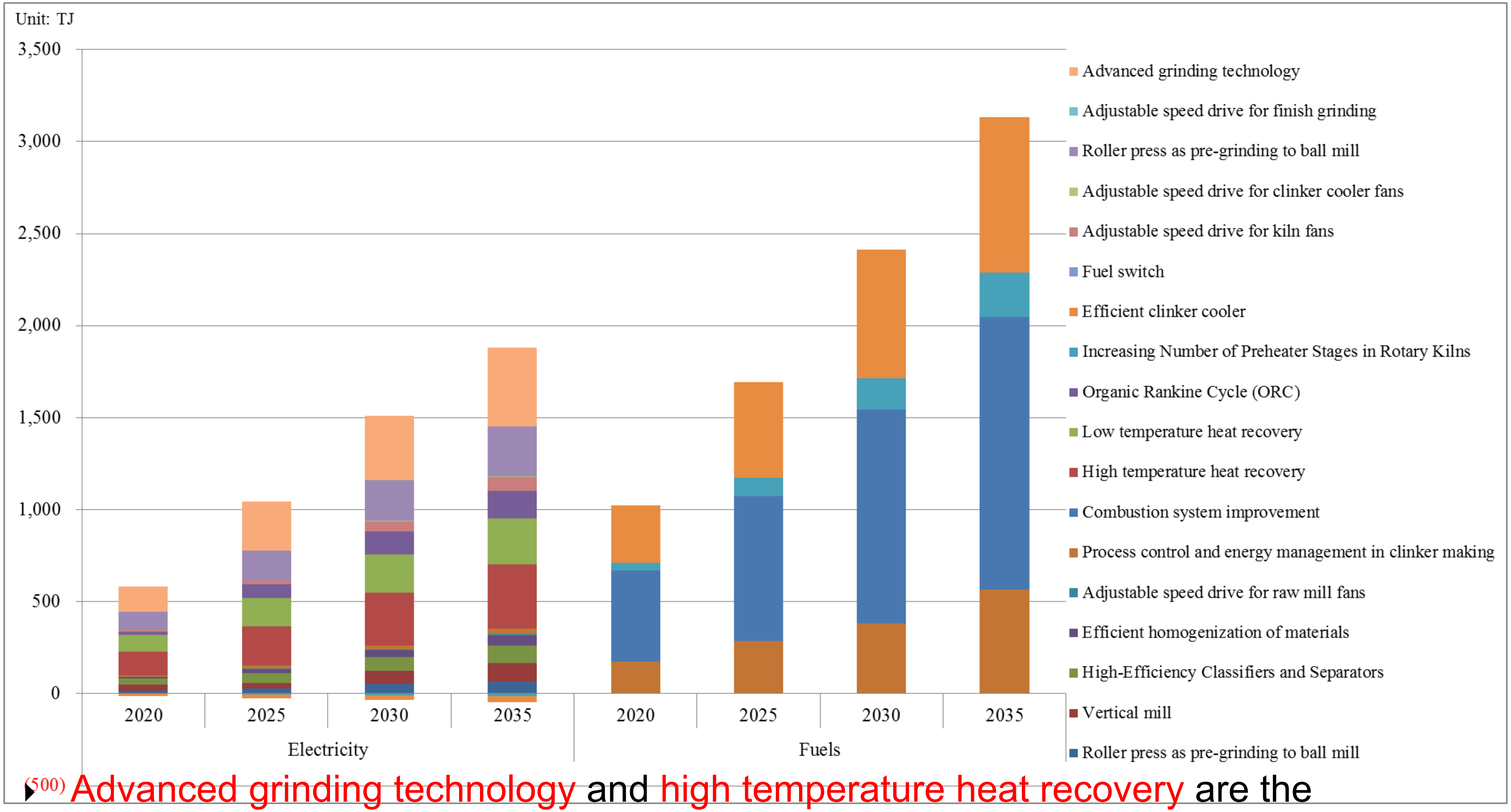
Unit: TJ

Energy type	Electricity				Fuels			
Scenario	BAU		Technical		BAU		Technical	
Process/Year	2025	2035	2025	2035	2025	2035	2025	2035
Raw material preparation	85.71	108.37	137.78	322.78	0	0	0	0
Clinker production	9.61	67.21	453.35	814.52	800.51	1245.72	1694.06	3130.73
Cement grinding	66.12	248.84	426.12	697.62	0	0	0	0
Total	161.44	424.42	1017.25	1834.92	800.51	1245.72	1694.06	3130.73
Share of electricity/fuels / total demand	1.7%	4.9%	11.7%	25.3%	2.0%	3.4%	4.3%	9.0%

- The saving potentials of each process are the sum of individual EETs allocated respective processes.
- Energy saving potentials amount to 25.3% for electricity and 9.0% for fuels in technical diffusion scenario compared to the frozen-efficiency until 2035. The BAU diffusion scenario is estimated at 4.9% for electricity and 3.4% for fuels.
- Clinker production has highest energy saving potentials.
- Compared to the clinker production process, the energy saving potentials in the raw material preparation and cement grinding process exist mainly for electricity.

Results (2/2)

Energy saving contribution by each energy efficient technology under technical diffusion scenario



- Advanced grinding technology and high temperature heat recovery are the technologies with the greatest potential for electricity savings, while efficient clinker cooler replacement, combustion system improvement and installation of energy management system make the greatest contribution to fuel savings.

Conclusions

- The analyzed 18 EETs would result in 4.9% and 25.3% saving potentials for electricity, and 3.4% and 9.0% saving potentials for fuels in BAU and technical diffusion scenario in 2035, respectively.
- The most influential technologies for technical electricity savings are advanced grinding technology and high temperature heat recovery.
- The largest part of technical fuel savings comes from combustion system improvement, efficient clinker cooler replacement and installation of process control and energy management system in clinker making.
- The simulation results also show the gap of EEI potentials between BAU and technical diffusion scenario is large. This may imply that these EETs will be implemented with further policy support. In other words, the government will need to make efforts on developing effective policies for the industry to exercise an extensive long term planning on energy savings.

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