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Technical roadmap on CO_2 emission reduction for China cement industry

WANG Jiajun, VP of Huaxin Cement

China cement industry has completed the great-leap-forward development

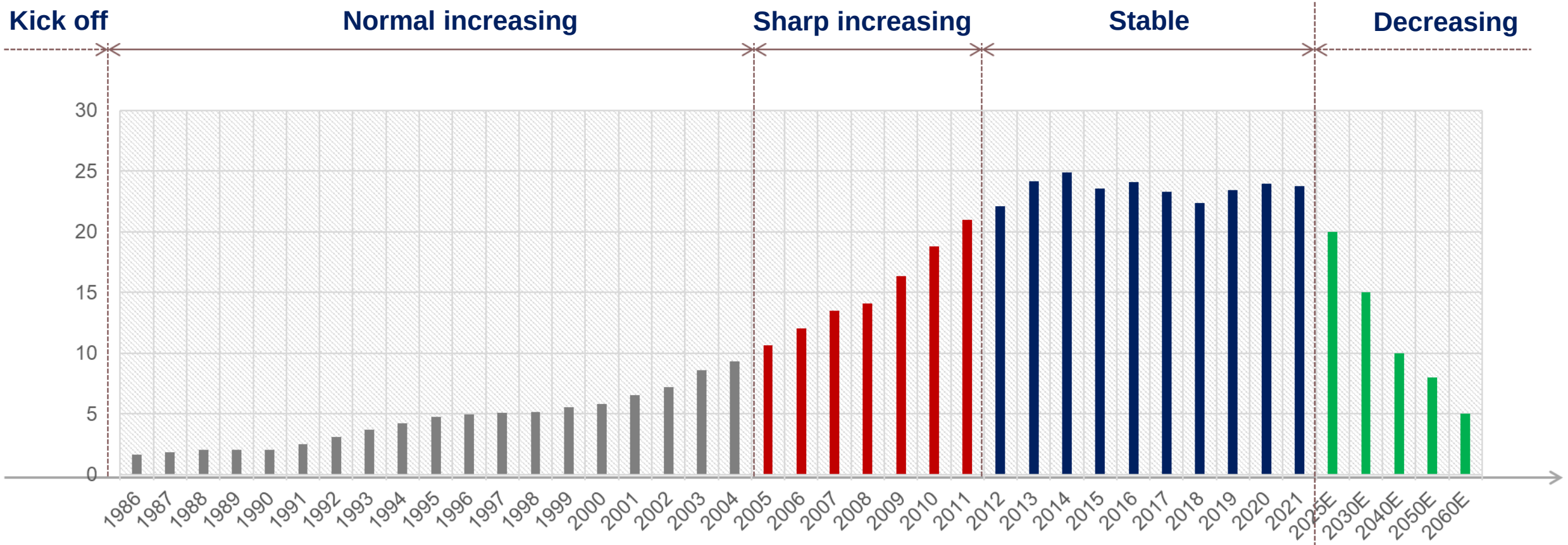
500 mil T, 1997

1 bil T, 2005

1.5 bil T, 2009

2 bil T, 2012

Cement production keeps 2.2-2.4 bil t for long time since 2012 and the peak is 2014, 2.44 bil T



From 1986 to 2021, 42.9 bil t cement consumed in China in 36 years

In next 40 years, 30+ bil t cement will be consumed

Data：National statistics

Future about China Cement Industry?

In the next 40 years, how many tons CO_2 will be emitted by cement industry?

1.3 bil t/a from China cement industry currently, this figure will be 0.15 bil t/a in 2060

(Currently:630kg/t, future: 300kg/t, On average: 400kg/t)

Currently 10 bil t/a from China (Global:40 bil t/a), Will be 2.5 bil t/a in 2060

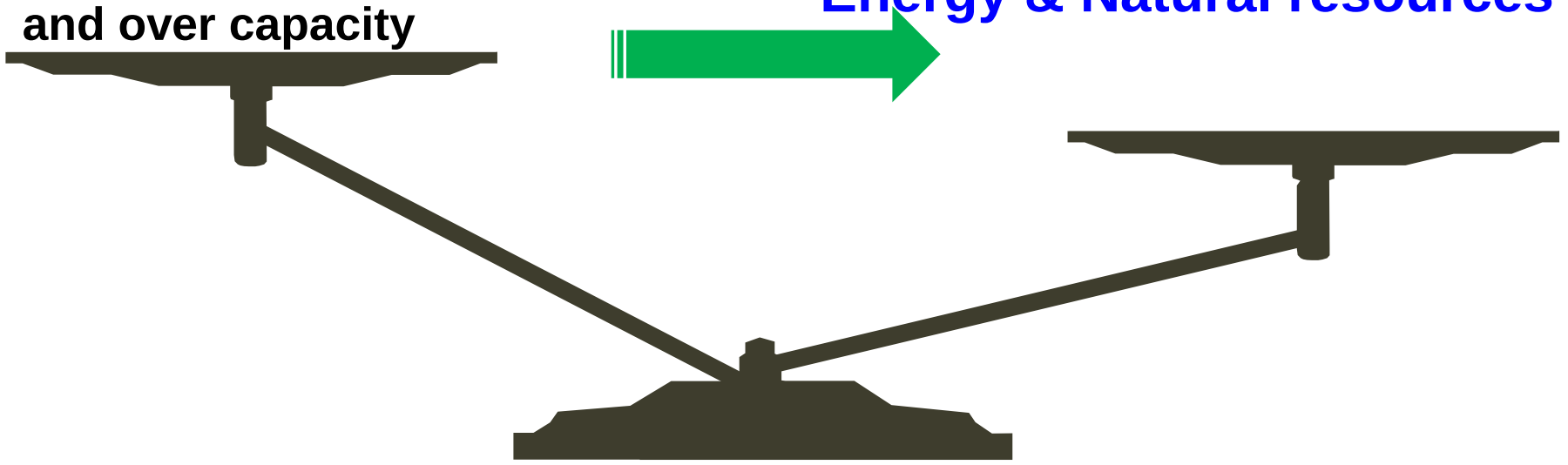
Capacity is the key &

Production pursues full

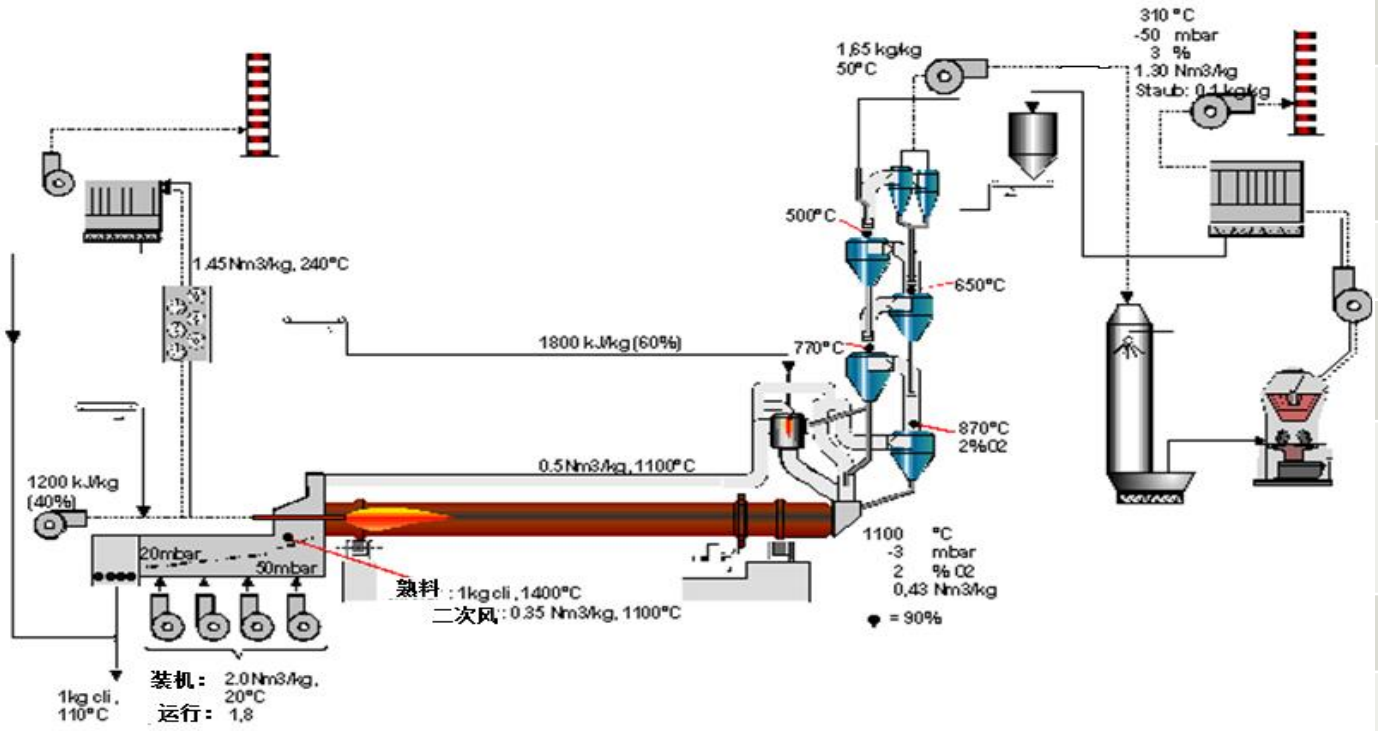
and over capacity

Reducing pollution & carbon emission

Energy & Natural resources saving



Key parameters _ kiln system

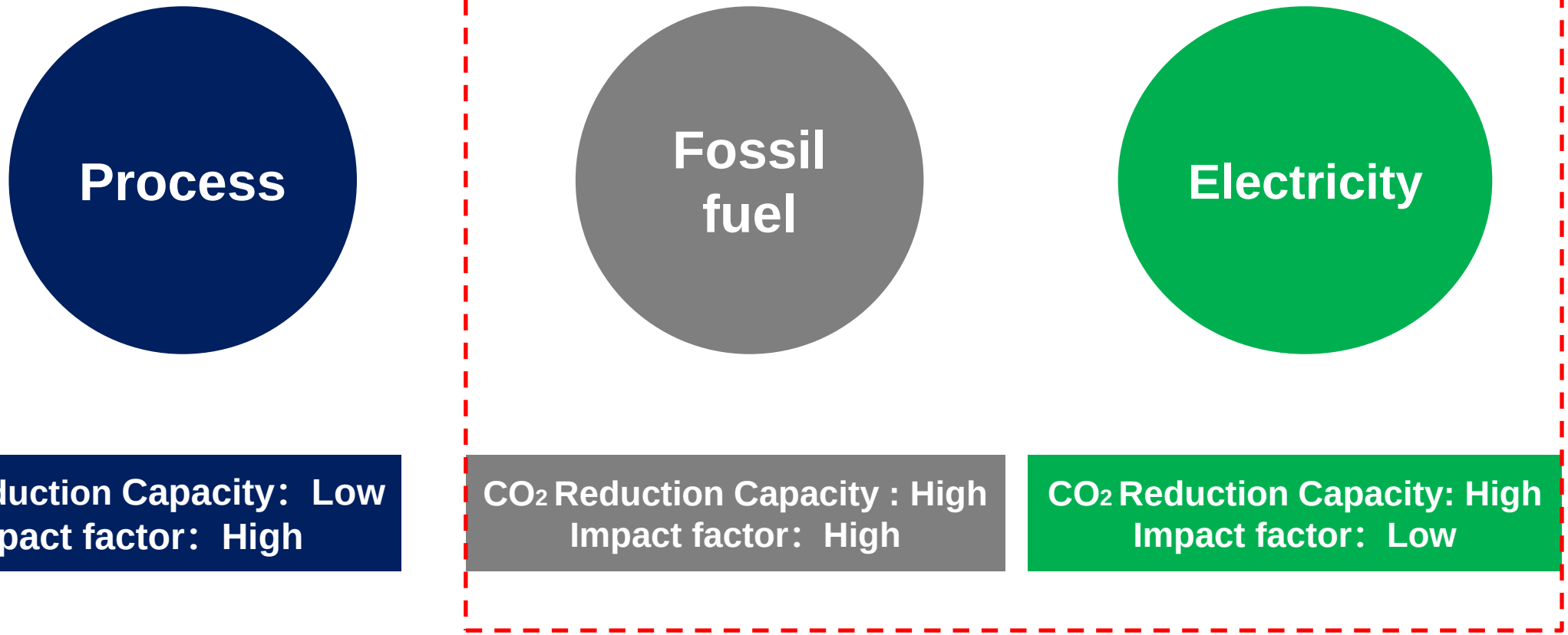


Capacity	1000~14000 tpd
Diameter	3.3~6.6 m
Length	50~105 m
L/D	10~16
Speed	2.5~5.5 rpm
Slope	3.5~4.0%
Specific Volume loading	3~5.5 t/m^{3}d
Specific Volume loading of burning zone	150~350 t/m^{2}d
Heat loading for	3~6 MW/m^2
Heat consumption	680~840 Kcal/Kg
Power consumption	15~30 KWh/t
NOx	50~400mg/Nm^3

Potential capacity on CO_2 reduction for China cement industry

Carbon trading & Alternative Decarbonated Raw Materials

Clean electricity & energy from electricity



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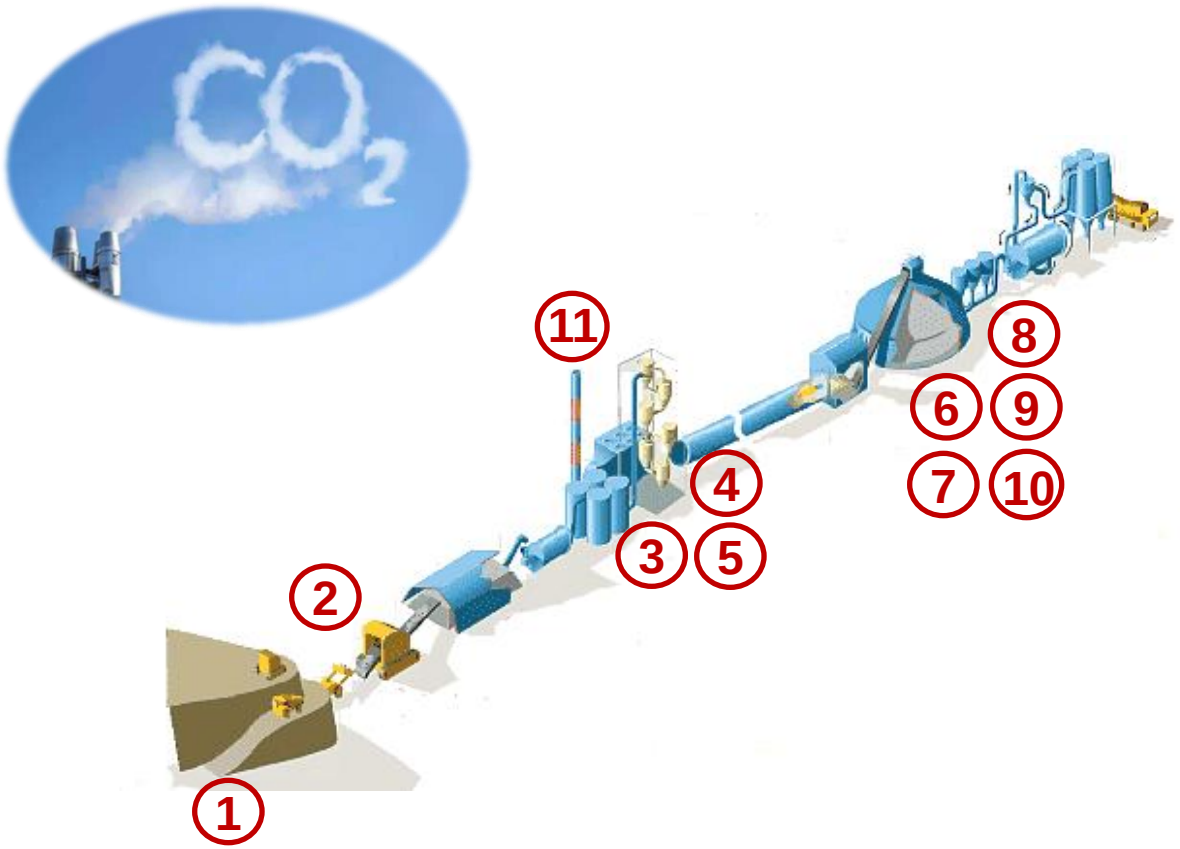

Based on: 860kg CO_2/t cli, 620kg CO_2/t cem

#	Technology	CO_2 Reduction capacity ($kgCO_2/t.cl$)	
		Low	High
1	Green Quarry	0.1	0.3
2	Alternative raw material	4	7
3	**Alternative fuels**	**140**	**285**
4	Combustion efficiency	20	50
5	Waste heat recovery	18	45
6	Clinker factor	120	170
7	Low carbon clinker	40	70
8	Energy efficiency	6	10
9	Intelligent industry system	5	10
10	New energy and utilization	30	60
11	CCUS	160	350

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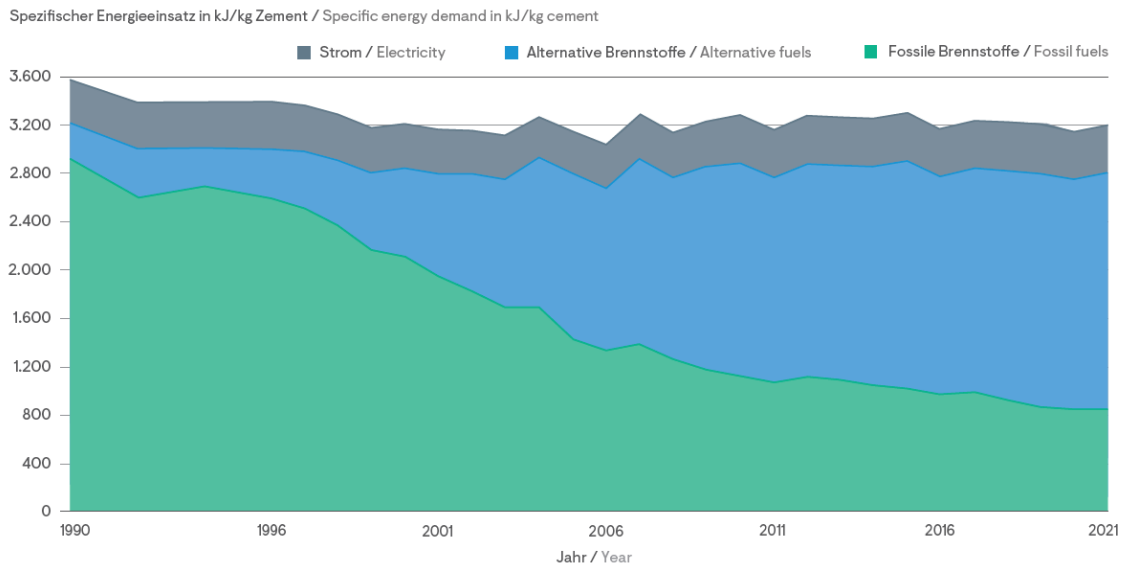
Increasing the AF volume Co-processed plays an important role for China cement industry in CO_2 emission reduction in _ Comparing with EU

- **Even though co-processing has been accepted and used more and more in China cement industry, the most profitable waste stream is HIW which can offer high tipping fee but low fuel substitution.**
- **Currently, TSR is less than 2% for China cement industry**

Fig. 4-1 Development of the specific fuel energy consumption



Data: CCA, VDZ

Table 3-3 Used quantity and average calorific value of alternative fuels in 2021

Alternative Brennstoffe / *Alternative fuel*	1.000 t	MJ/kg
Altreifen / *Waste tyres*	166	28
Altöl / *Waste oil*	70	27
Fraktionen aus Industrie-/Gewerbeabfällen / *Fractions of industrial and commercial waste:*		
- Zellstoff, Papier und Pappe / *Pulp, paper and cardboard*	65	4
- Kunststoff / *Plastics*	932	23
- Verpackungen / *Packaging*	–	–
- Abfälle aus der Textilindustrie / *Wastes from the textile industry*	–	–
- Sonstige / *Others*	1.044	20
Tiermehle und -fette / *Meat and bone meal and animal fat*	143	18
Aufbereitete Fraktionen aus Siedlungsabfällen / *Mixed fractions of municipal waste*	524	20
Altholz / *Waste wood*	1	13
Lösungsmittel / *Solvents*	133	25
Bleicherde / *Fuller's earth*	–	–
Klärschlamm / *Sewage sludge*	665	3
Sonstige, wie: / *Others, such as:*	113	5
- Ölschlamm / *Oil sludge*		
- Organische Destillationsrückstände / *Organic distillation residues*		

MSW & Non-hazardous industry waste is the best AF sources for China cement industry

MSW:

High volume、NCV of fresh MSW is about 1000kcal/kg，after pre-processing，the NCV of AF from MSW can reach 1500-3000kcal/kg。

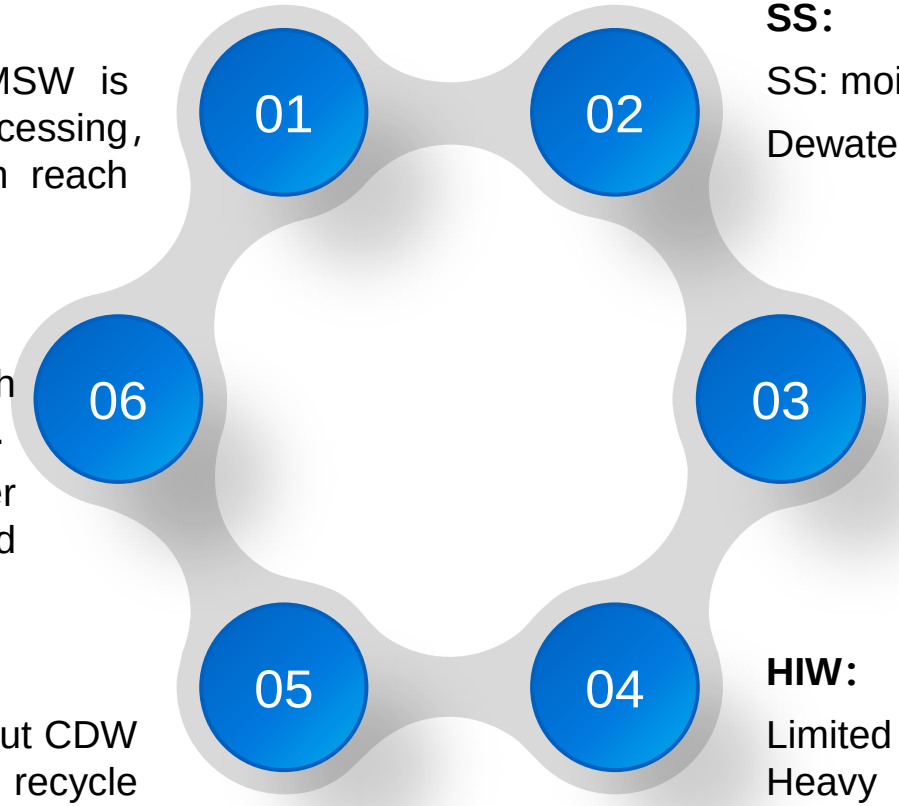
FM & Biomass:

FM: Sources are limited with seasons, high moisture and alkali.

Biomass: High alkali & low S, after drying can be burn with limited NCV.

CDW & Slag：

Slag is recycled very well but CDW is with low percentage for recycle less than10%。



SS:

SS: moisture>80%:

Dewatered SS: moisture<60%; negative CV

Non-hazardous IW（with organic）：

Plastic, paper, textile waste. Fresh business section in China.

HIW:

Limited volume, H&S is the key factor including Heavy metal issues. High NCV solvent has reached a high recycle level.

- **MSW is the best AF source with suitable pre-processing, can take important role in CO_2 reduction with high feeding rate for co-processing.**

New type precalciner to achieve better AF combustion

On-line precalciner: precalcine+ better AF combustion + lower NOx + higher TSR

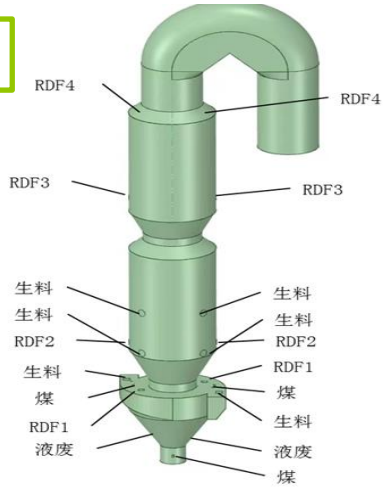
4 combustion zones with different function:

- NOx reduction with low O_2 (Turbulence room Bottom)
- Light AF combustion (turbulence room mid & up and precalciner bottom)
- Small-size AF combustion (Precalciner mid)
- Big-size & heavy AF combustion (Precalciner upper)

HuaXin

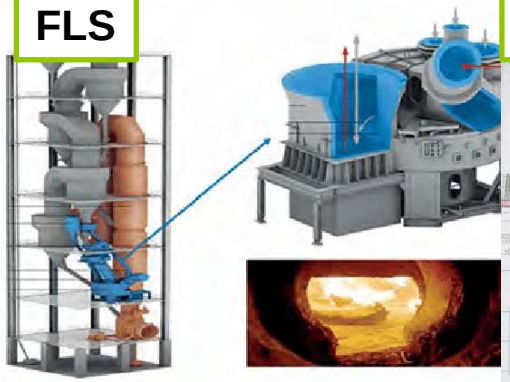
Double tertiary air injection、3 times turbulence、more stages combustion precalciner:

- Tertiary air is injected to turbulence in 2 directions
- 3 times air turbulence in precaiciner
- Different type AF, RM & coal feeding with many points
- NOx reduction in combustion process by CMSW & coal at the bottom of precalciner

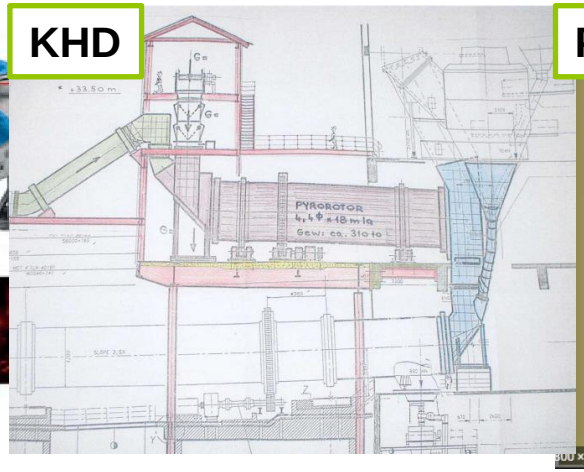


Off-line pre-combustion/gasification: limited on burning and operation, cannot reach a higher TSR & avoid pollution, only for low pre-processing cost by less shredding & sorting.

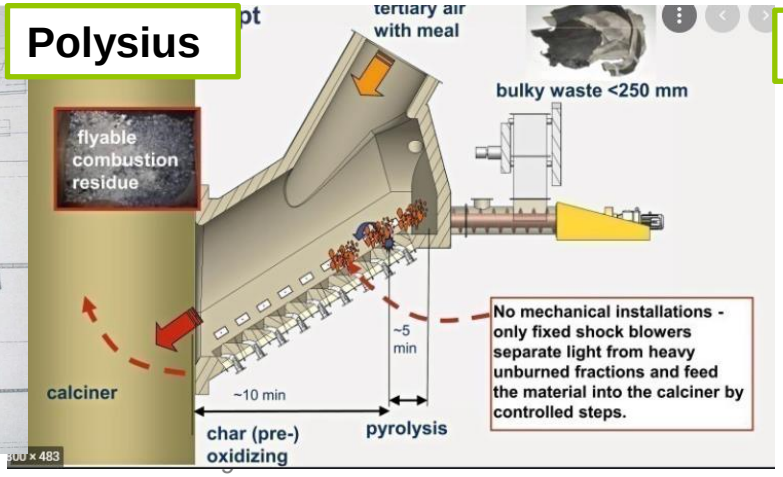
FLS



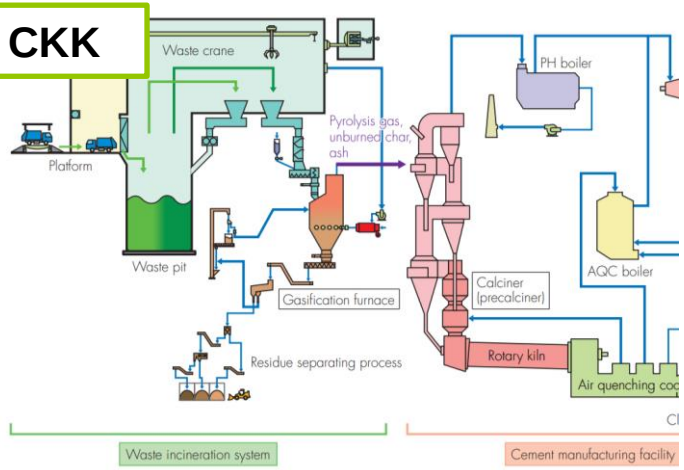
KHD



Polysius



CKK



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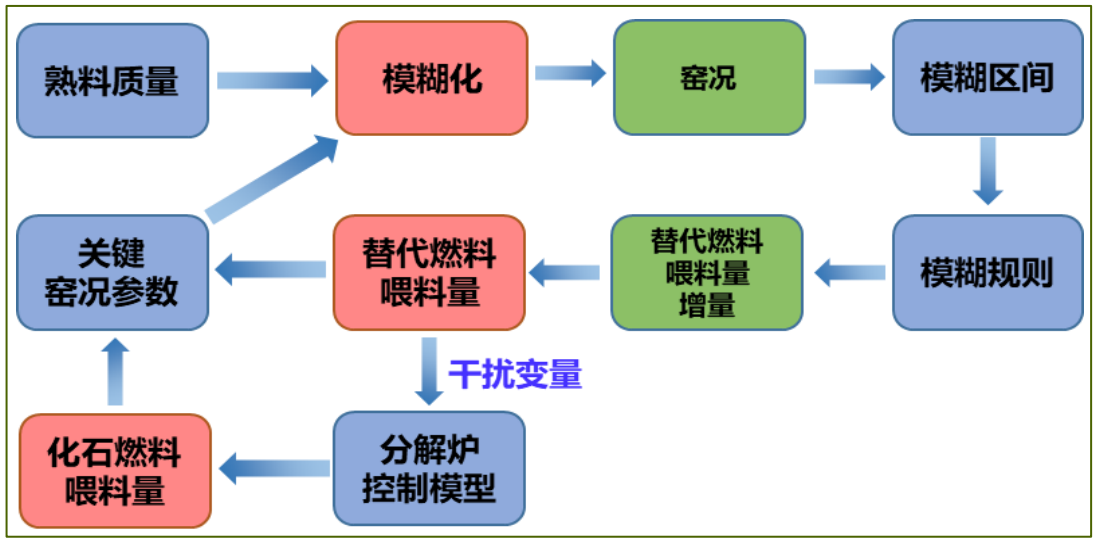
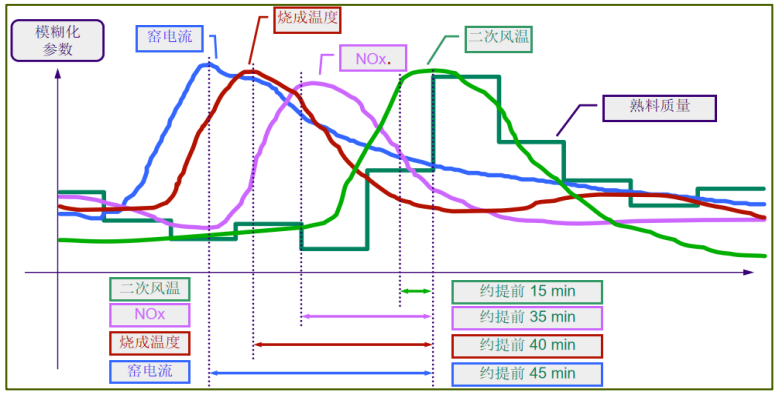
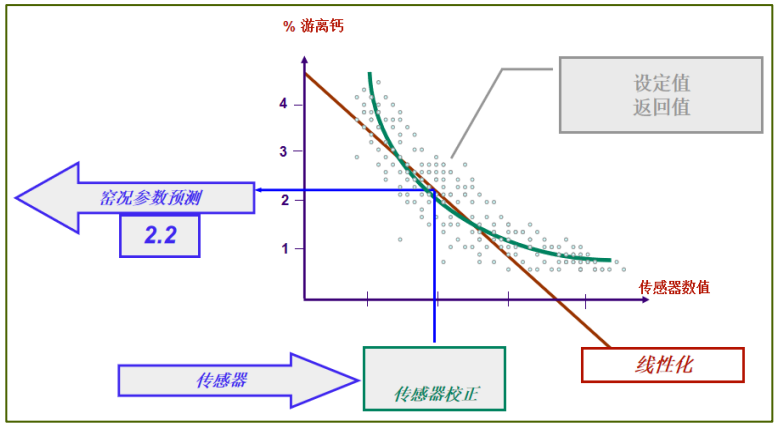
With digital & AI technology, maximizing AF feeding rate by analyzing & pre-judging kiln operation & clinker quality

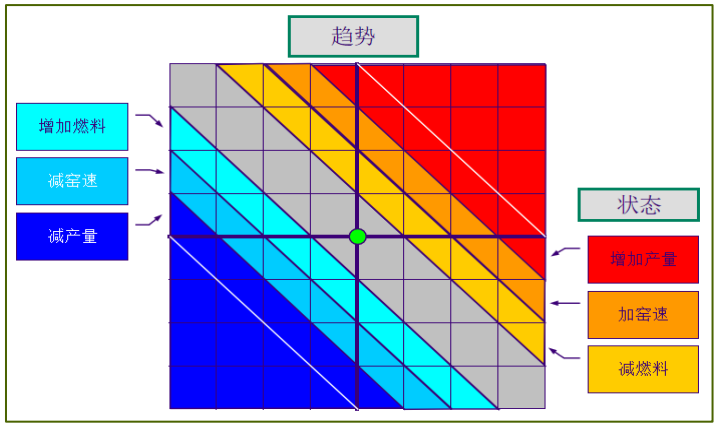




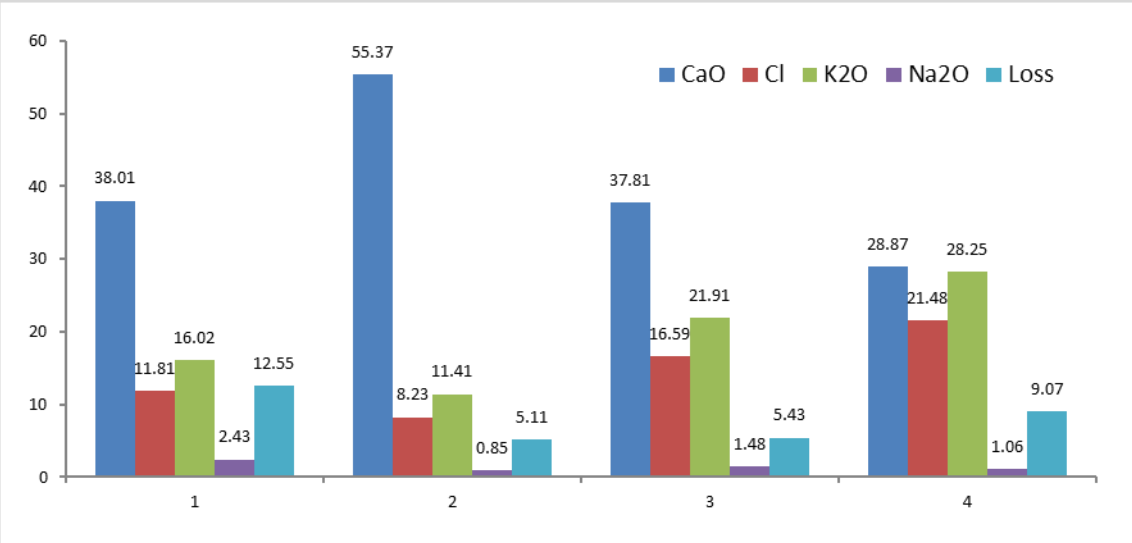
Pre-judge the kiln operation



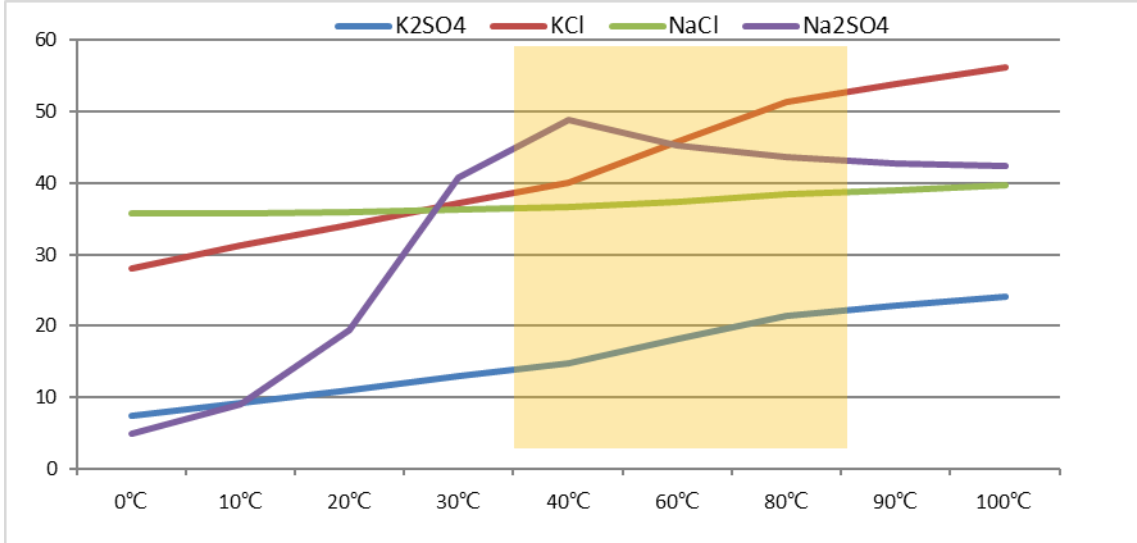
Adjusting the fuel, clinker & kiln speed (AF is the 1st priority) based on the pre-judging



KCl producing from by-pass dust



Component of by-pass dust



Solubility of K & Na salt with temperature

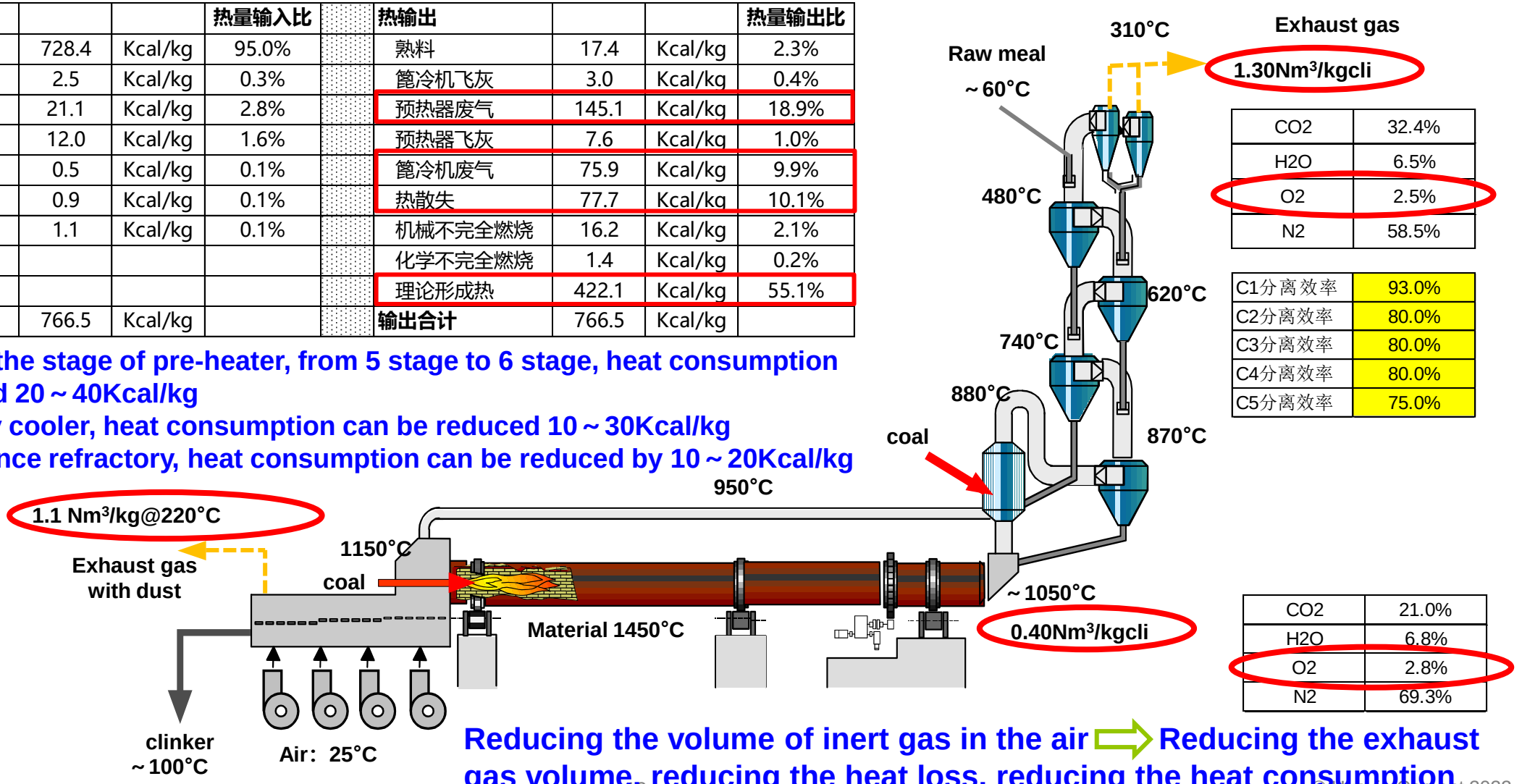
- 80% of by-pass dust is CaO、Na_2O、K_2O、Cl & Loss，K is 7.4～29.9 times of Na, K_2SO_4 solubility less than KCl under the same temperature.
- **Solubility of K_2SO_4 & KCl** increase as temperature goes up
- Fluctuation of NaCl solubility with temperature is limited, solubility of Na_2SO_4 at temperature above 30℃ is quite high and keeps stable.
- **Take advantage of the solubility for different salts at different temperature**, extracting potash with high purity
- The technology process: “washing+separating+extracting”。

Reducing the kiln heat consumption _ By kiln system upgrades

A typical heat balance from a good operation kiln system（basis: 1kg cli）:

热输入			热量输入比		热输出			热量输出比
燃料输入	728.4	Kcal/kg	95.0%		熟料	17.4	Kcal/kg	2.3%
燃料显热	2.5	Kcal/kg	0.3%		篦冷机飞灰	3.0	Kcal/kg	0.4%
生料显热	21.1	Kcal/kg	2.8%		预热器废气	145.1	Kcal/kg	18.9%
篦冷机鼓风	12.0	Kcal/kg	1.6%		预热器飞灰	7.6	Kcal/kg	1.0%
一次风	0.5	Kcal/kg	0.1%		篦冷机废气	75.9	Kcal/kg	9.9%
输送风	0.9	Kcal/kg	0.1%		热散失	77.7	Kcal/kg	10.1%
漏风	1.1	Kcal/kg	0.1%		机械不完全燃烧	16.2	Kcal/kg	2.1%
					化学不完全燃烧	1.4	Kcal/kg	0.2%
					理论形成热	422.1	Kcal/kg	55.1%
输入合计	766.5	Kcal/kg			输出合计	766.5	Kcal/kg	

- By increasing the stage of pre-heater, from 5 stage to 6 stage, heat consumption can be reduced 20～40Kcal/kg
- High efficiency cooler, heat consumption can be reduced 10～30Kcal/kg
- High performance refractory, heat consumption can be reduced by 10～20Kcal/kg



CO2	32.4%
H2O	6.5%
O2	2.5%
N2	58.5%

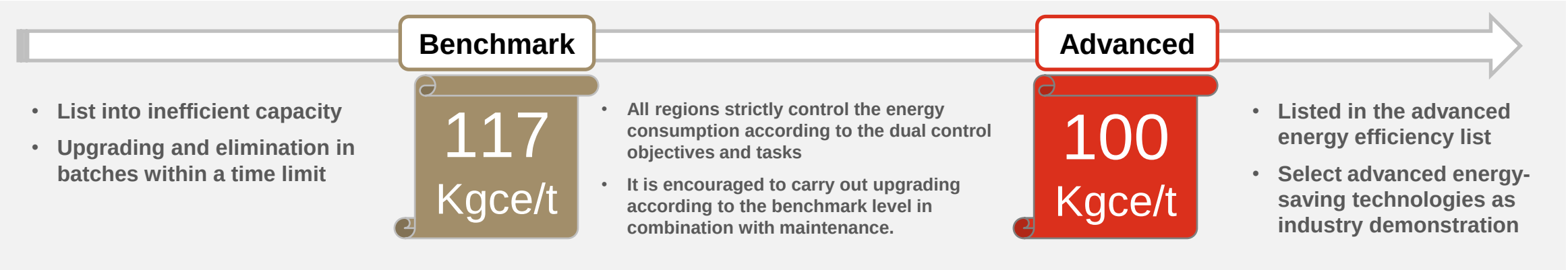
C1分离效率	93.0%
C2分离效率	80.0%
C3分离效率	80.0%
C4分离效率	80.0%
C5分离效率	75.0%

CO2	21.0%
H2O	6.8%
O2	2.8%
N2	69.3%

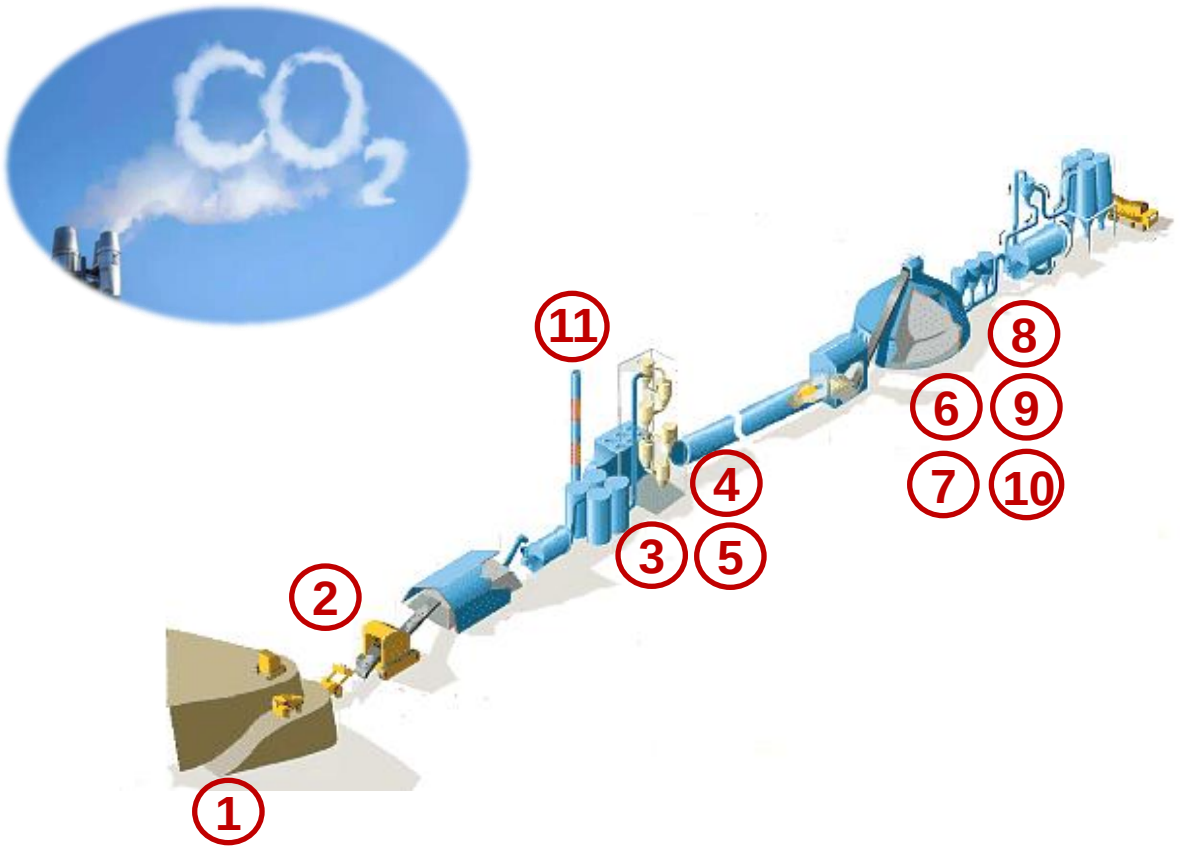
Reducing the volume of inert gas in the air ⇨ Reducing the exhaust gas volume, reducing the heat loss, reducing the heat consumption

Under Carbon Reduction, energy efficiency compliance is the lifeline of cement enterprises in the future

- **“Control both the total amount and intensity of energy consumption" is an important starting point for realizing the national strategic decision of “Carbon peaking and Carbon neutralization", and it is also the focus for the cement industry to eliminate excess and backward capacity in the future.**
- **According to the requirements of the national management and control of the "High energy consumption and high emissions" projects, the government will strictly promote the project to improve efficiency and meet the standards in accordance with the classification of the comprehensive energy consumption level of clinker.**



Technical roadmap on CO_2 emission reduction for China cement industry



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#	Technology	CO_2 Reduction capacity ($kgCO_2$/t.cl)	
		Low	High
1	Green quarry	0.1	0.3
2	Alternative raw material	4	7
3	Alternative fuels	140	285
4	Combustion efficiency	20	50
5	**Waste heat recovery**	**18**	**45**
6	**Clinker factor**	**120**	**170**
7	Low carbon clinker	40	70
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Promoting the kiln heat efficiency is another possibility for China cement industry

Energy efficiency:

--Exhaust gas temperature _ preheater：90℃，Heat：252KJ/kgcli

--Exhaust gas temperature _ cooler：70℃，Heat：118KJ/kgcli

--Clinker temperature：110 ℃，Heat：86KJ/kgcli

--Heat in gas after waste heat recovering：432KJ/kgcli

--System heat loss：380KJ/kgcli

--Heat in by fuel：3050KJ/kgcli

--Heat in by air：186KJ/kgcli

Energy efficiency calculation:

η=1-（252+118+86+432+380）/（3050+186）=60.9%

Noted: Exhaust gas from cooler for raw material drying.

It is limited to reduced the exhaust gas temperature further more, within the existing waste heat recovery technology, how to improve the energy efficiency?

Compared with power generation, is there any other way for the steam utilization from waste heat recovery to reach a higher energy efficiency?

High volume utilization of inorganic solid waste is one of the key factors for China cement industry in pollution & CO_2 emission reduction and it will be kept & enlarged in the future

Clinker factor can be as low as 0.5~0.65，in other countries it is above 0.8，even though, this factor can be lower in the future. Since fly ash & slag volume will be decreased due to CO_2 emission reduction in other industry, producing 42.5 or higher grade cement with clinker factor 0.5 will take more and important role.

Solid waste	Volume increased /a	Recycling percentage currently	Possibility in future
Blast furnace slag	~200 mil t	~100%	
Fly ash	~600 mil t	~70%	Can be 100%
Slag	~150 mil t	~30-40%	Can be 100% recycled with innovation
Gypsum-by products	~200 mil t	~50%	Can be 100%
Coal gangue	~800 mil t	~30%	low temperature clinker burning, MIC for cement & Concrete
CDW	~ 2-3 bil t	~10%	Granulated CDW（4200cm^2/g）as MIC, can be recycled 30%；as cement, fineness should be 5600cm^2/g

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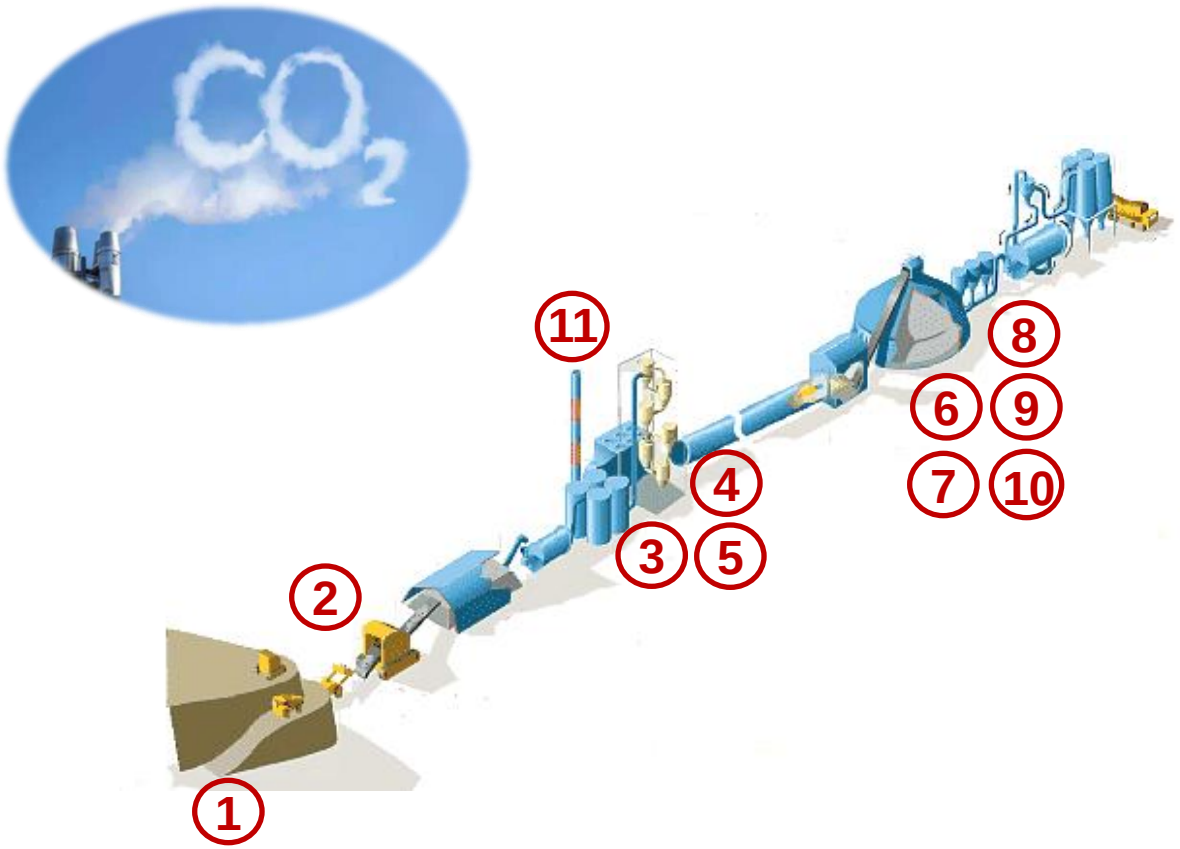

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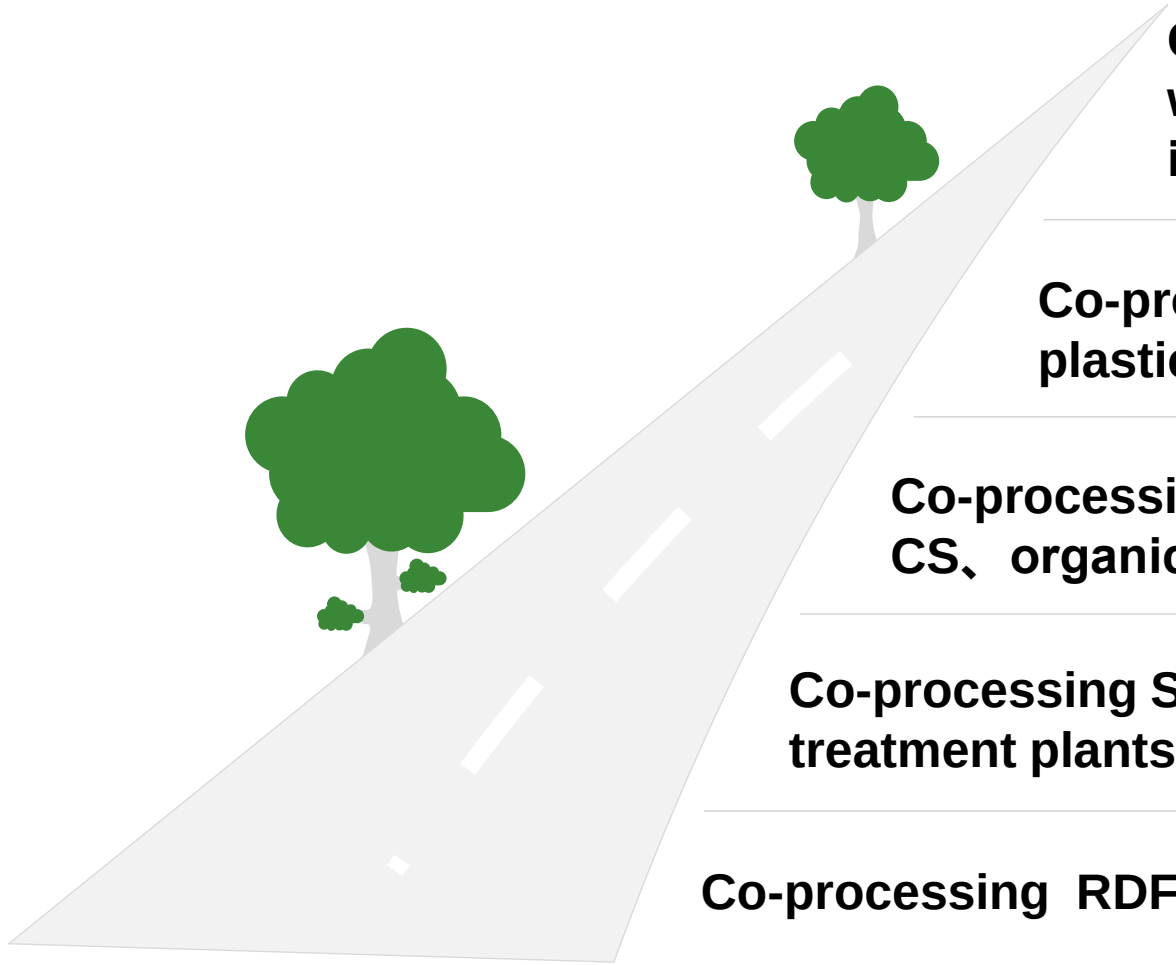
- **100% AF with ZERO fossil fuel**
  - **Compensated by solar energy for electricity → water cleavage to produce H_2 → H_2 replaces fossil fuel**
- **Carbon neutral concrete**
- **Low-Ca clinker**
  - **Blite-Sulpho-Aluminate Clinker (SAC)& Ferro-Aluminate Clinker (FAC), low-heat clinker, combined clinker & MIC, Cement additives**

Technical roadmap on CO_2 emission reduction for China cement industry

- **Produce clinker with the major minerals are CS、C_2S_2、r-C_2S**
- **Re-carbonation of CO_2 in the exhaust gas with pozzolan material to produce cement-based products**
  - **Exhaust gas utilization: strengthening the curing procedure by exhaust gas to replace steam curing for re-carbonation**
  - **CCUS:**
    - **Capture and pure $CO_2$from exhaust gas and re-carbonate no-steel concrete.**
    - **CDW re-carbonation for aggregate & MIC**

Cement industry will play an integrated role in environmental protection, low carbon and green industry in the future



Co-processing inorganic solid industry waste（slag、fly ash from other industries……）

Co-processing combustible waste（FM、plastics、textile、waste oil，animal meal……）

Co-processing HIW（fly ash from MSW incinerator、CS、organic solvents & industry waste……）

Co-processing SS（cooperated with waste water treatment plants ）

Co-processing RDF in environmental, OH&S friendly way

Technical models of cement industry in the future for China cement industry

1. Zero fossil fuel，co-processing AF produced from waste and biomass，green hydrogen as complement
2. Using Alternative Decarbonated Raw Materials/waste to produce low carbon clinker, zero natural raw material consumed
3. Low clinker factor cement with high volume of fineness grading MIC to make zero carbon emission concrete
4. Zero electricity purchasing with hot steam producing building materials products to achieve negative carbon emission
5. Exhaust gas utilization, producing building materials with CO2 curing, CCUS
6. Intelligent operational system, automatic control & operation system for pre & co-processing, IoT covers from raw materials to customer


Thanks for your patience
清洁我们的生活环境 提供信赖的建筑材料
Clean Our Living Environment Provide Reliable Building Materials