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LC^3 A GIANT LEAP TO SUSTAINABILITY

Dr. Hans Wilhelm Meyer & Piet Hein Heersche

CEMCON AG – SWITZERLAND

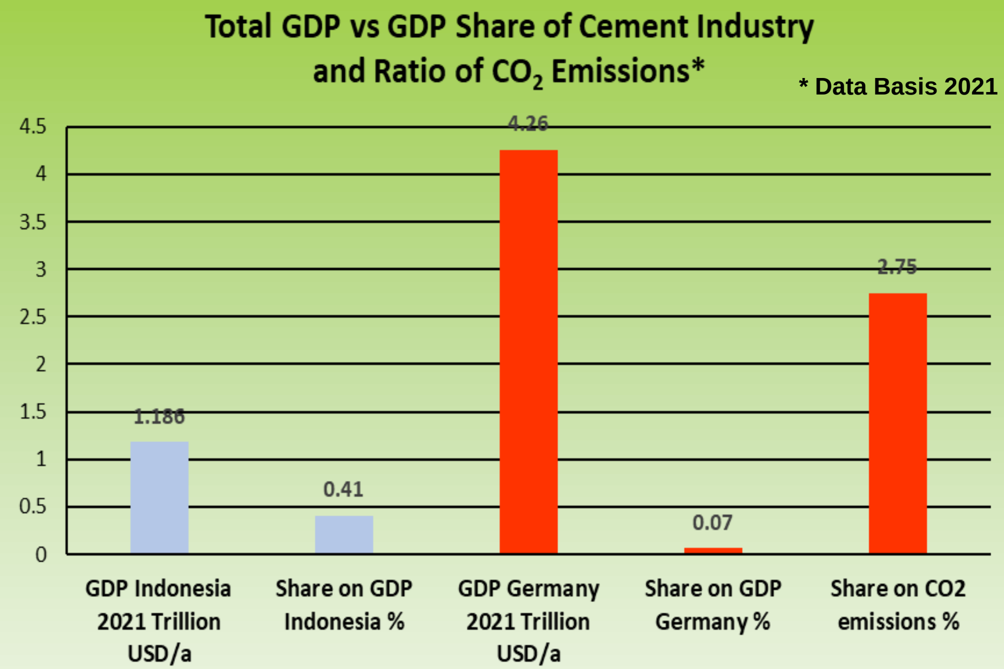
AT CEMTENTRADE ASIA 2024
Manila 23.04.-24.04.2024

CEMENT INDUSTRY UNDER PRESSURE

- **Cement is a product of strategic nature for every country. There is no substitution for cement today.**

- **Manufacturing of cement is the second most energy consuming large scale industrial process.**

- **The nature of clinker manufacturing is the decarbonation of limestone combined with huge combustion of thermal fuels (approximately 750 kcal/kg of clinker) and high electrical energy demand (approximately 95 kWh/t of cement). In total combined approximately 840 kcal/kg clinker.**



- **All in all this ends up in roughly 0.8 to 0.9 T of CO_2 emissions per T of cement.**

- **Though cement is an essential material, the share of cement industry on the GDP of post industrial countries, e.g. Germany as, well as of emerging nations, e.g. Indonesia is marginal.**

- **Worse: The share of total CO_2 emission of Germany vs the GDP is at factor 39. This is the reason why the cement industry is under growing pressure from politics, environmentalists and finally from the society.**

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MAJOR SOURCES OF CO_2 EMISSIONS IN CEMENT PRODUCTION

- **Decarbonation of limestone:**

$$CaCO_3 \xrightarrow{875\ \text{Deg. C}} CaO + CO_2\uparrow$$

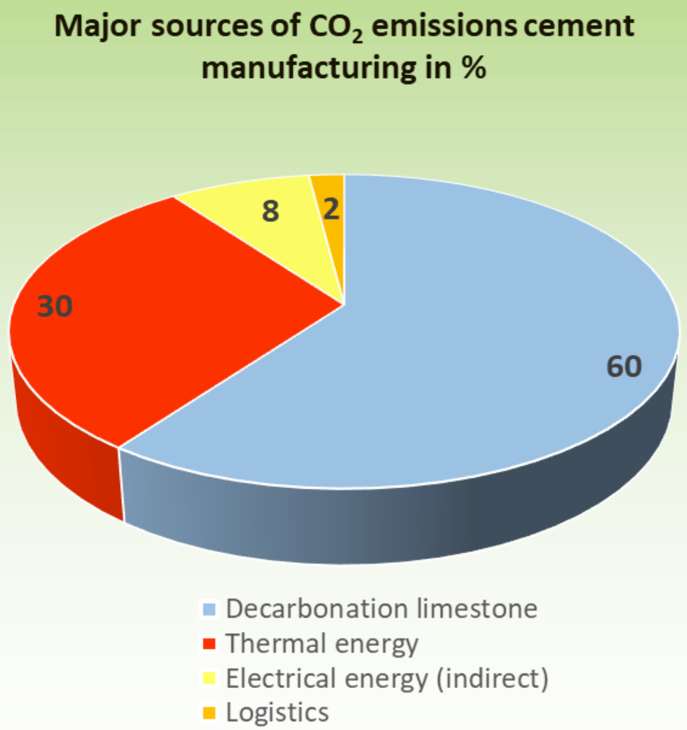
It is the major source of CO_2 emissions in cement production. It contributes to approximately 60 % to the overall CO_2 emissions. The decarbonation of limestone is exclusively attributed to clinker manufacturing process.

- **Further 30 % of the total CO_2 emissions are related to thermal CO_2 from combustion materials. Whereas coal, oil and gas are considered primary fuels and agricultural, industrial and municipal waste materials are secondary fuels or reflected as AFR (alternative fuels and raw materials).**

- **In total approximately 90 % of the CO_2 emissions for cement production are originating from the clinkering process.**

- **Only 8 % of the total CO_2 emissions in cement production are related to electrical energy. Here again clinker manufacturing contributes to the main share of approximately 5 % and cement grinding is causing approximately 3 % of the CO_2 emissions.**

- **Logistics and other minor sources are making up only 2 % of the CO_2 emissions.**



HOW TO REDUCE CO_2 EMISSION?

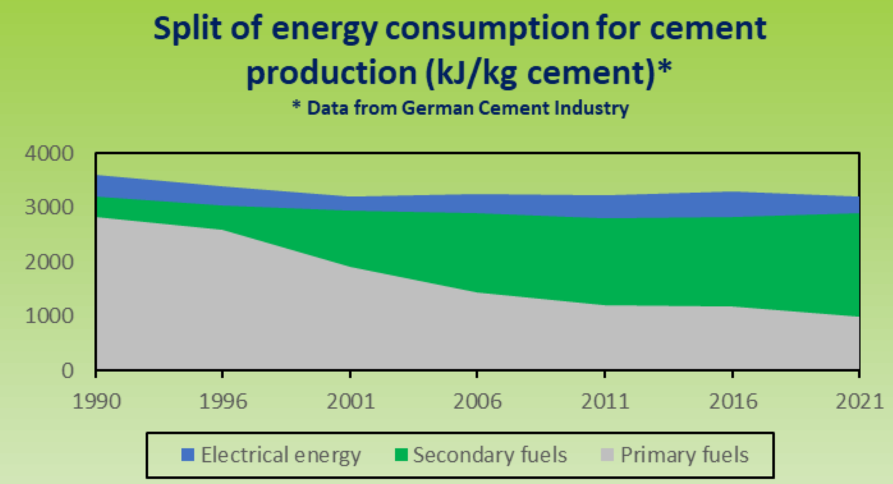
- There is a manifold of opportunities ranging from optimization of preheater efficiency to hauling of raw materials by electrical trucks. But most of all options result in marginal CO_2 emission savings.

- However there are three options with major CO_2 emission saving impact:

A) REPLACEMENT OF PRIMARY FUELS BY AFR: Average substitution rate in ASEAN is below 20 %. In post industrialized countries most thermal energy is created by AFR. Hence there is huge potential in Asia for further improvement.

B) GENERATION OF ELECTRICAL POWER BY RENEWABLE SOURCES:
In many plants Waste Heat Recovery Systems (WHRS) are installed and installation of solar farms or wind power is accelerating.

C) REDUCTION OF CLINKER RATIO IN CEMENT: This means reduce or stop production of OPC and switch to PCC (Portland Composite Cements). The reduction of the cement to clinker factor is considered to bears most significant CO_2 emission savings impact.



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SUBSTITUTION MATERIALS (ADDITIVES) FOR CLINKER

- **A series of materials are available to substitute clinker:**
- **Those materials can be categorized into natural and artificial latent hydraulic materials and none hydraulic additives.**
- **The availability of additives to reduce clinker differs strongly locally/regionally.**
- **But in Asia CC/LC³ is available everywhere due to significant laterite and clay resources.**
- **Consequence: LC³ and CC is in the lime light to substitute cement clinker.**

LATENT HYDRAULIC MATERIALS	Material
Natural latent hydraulic additives	Additives of volcanic origin, e.g. Pozzolana, Trass
Artificial latent hydraulic additives	GBFS
	Copper slag
	Fly ash
	Calcined clay, LC³
	Silica foam
NONE HYDRAULIC ADDITIVES (FILLERS)	**Material**
	Limestone
	Basalt

Availability of Additives in selected Asian countries						
Country	Pozzolana	GBFS	Fly ash	Limestone	Basalt/Andesite	**LC³/CC**
India		X	X	X	X	**X**
Sri Lanka				X		**X**
Bangla Desh			X			**X**
Thailand		X		X		**X**
Indonesia	X	X	X	X	X	**X**
Philippines	X		X	X	X	**X**
Vietnam		X	X	X		**X**
Malaysia		X	X	X		**X**
Cambodia				X		**X**

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WHAT IS CC/LC^3?

- **LC^3 stands for Limestone & Calcined Clay Cement and CC for Calcined Clay.**

- **Not every clay is suitable for LC^3. The reactive compound is the Kaolin mineral, a two layered silicate. Between the tetraedric silica layers are aluminum-hydroxy layers. The hydroxy (OH^-) groups are exchangeable and result in the pozzolanic reactivity and performance of LC^3.**

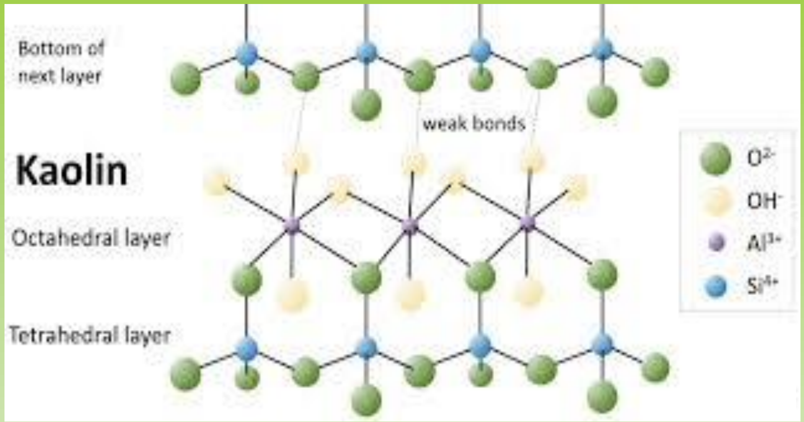
- **Target of the calcination is the dihydroxylation of the Kaolin into Metakaolin at 700 – 850 deg. C.**

- **The layered structure of the Metakaolin with its high surface results in excellent hydraulic reactivity and compressive strength development.**

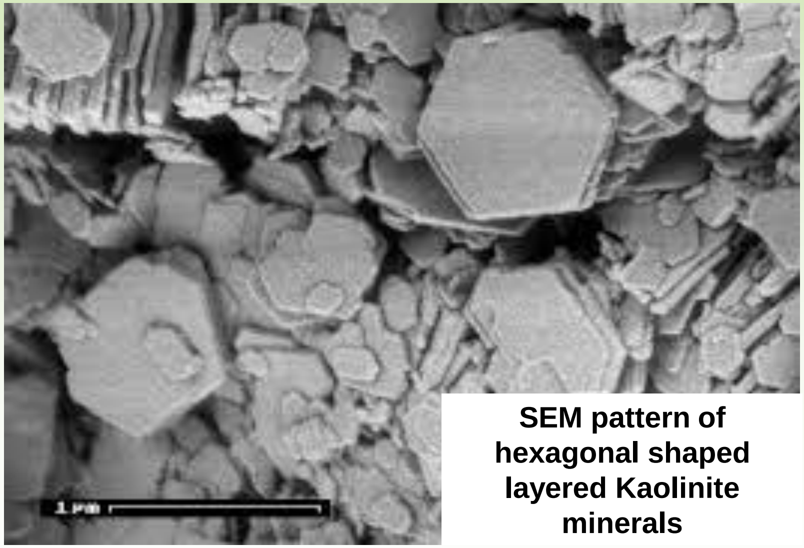
- **In order to determine the pozzolanic performance of LC^3, testing of mortar and concrete have to be carried out using CC as an additive. Suitable clay includes a minimum of 30-40 % of Kaolin.**

- **LC^3 contains ideally 40-60 % of CC.**

- **Clay sources shall be over- or under-burden of quarries, basically turning waste material into a commercial good. Agricultural soils shall not be converted into LC^3.**



Schematics of layered Kaolinite structure

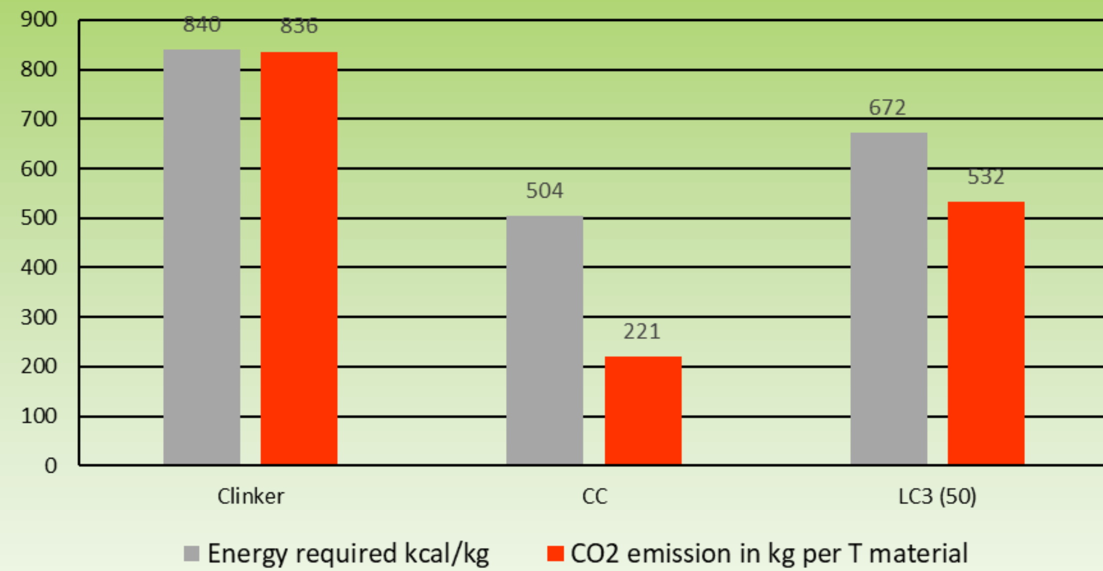


SEM pattern of hexagonal shaped layered Kaolinite minerals

CO_2 SAVINGS BY LC³

- **CC requires only approximately 60 % of the thermal energy for the dihydroxylation of Kaolin into Metakaolin compared to clinker and also does not has any significant emission of CO_2 through decarbonation.**
- **Hence CO_2 emissions of CC are only at 26.4 % compared to clinker emissions.**

Specific Energy Consumption and CO_2 Emissions Clinker, OPC and LC³ (50)



- **Turned into LC³ at a clinker substitution rate of 50 %, CO_2 emissions reduction is 36.3 % compared to OPC.**

STATUS OF LC^3 TECHNOLOGY

- **The production of calcined clay cements is not considered a new process technological innovation, calcined clay (and cements) having been produced for decades, through rotary kilns, in countries such as Brazil, India and the United Sates.**

- **Using cost efficient production mechanisms for clay calcination, two modernized calcination processes have emerged for installation: A dual rotary kiln technology and a flash calciner technology.**

- **Dehydroxilation (calcination) requires a temperature of 700-850 deg. C, depending on the quality of the clay resulting in much lower energy demand and CO_2 emission compared to clinker production.**

- **Flash calciner systems are more energy efficient and result in higher quality CC compared to dual rotary kiln systems and are most suitable for green field installations.**


“Flash Calciner” Technology LC3 plant with ~1000 TPD capacity in Cameroon

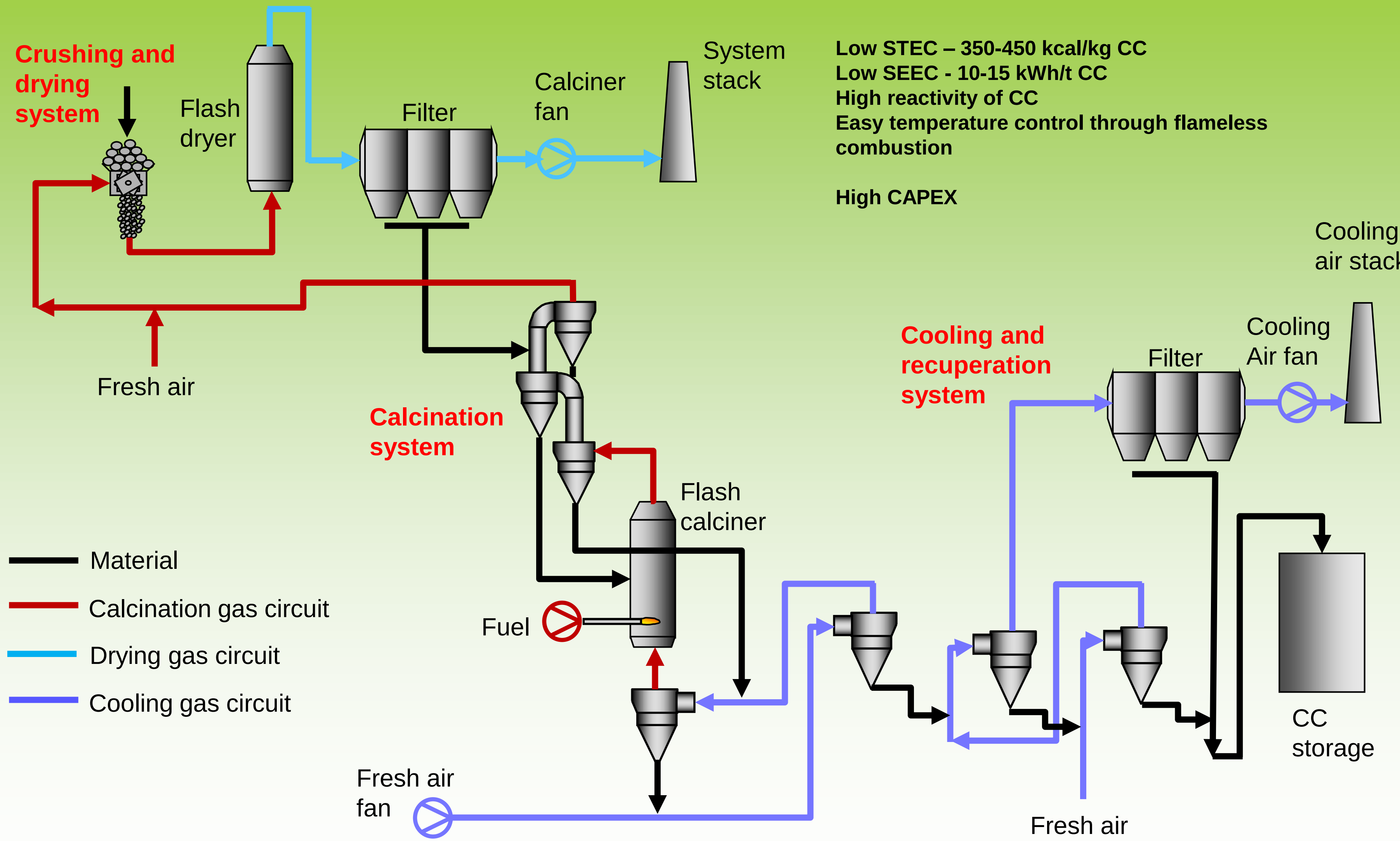
- **However dual rotary kiln systems are simpler and lower CAPEX. This technology is more applicable in case of conversion of existing clinker kiln lines.**

- **At present, Thyssen Krupp Industrial Solutions (Polysius) as well as FLSmidth have installed their first flash calciner systems, both located in Africa. OEM’s including Sinoma (China), KHD (Germany), FCT (Australia) and FCB (France) and others are also positioning themselves in the market.**

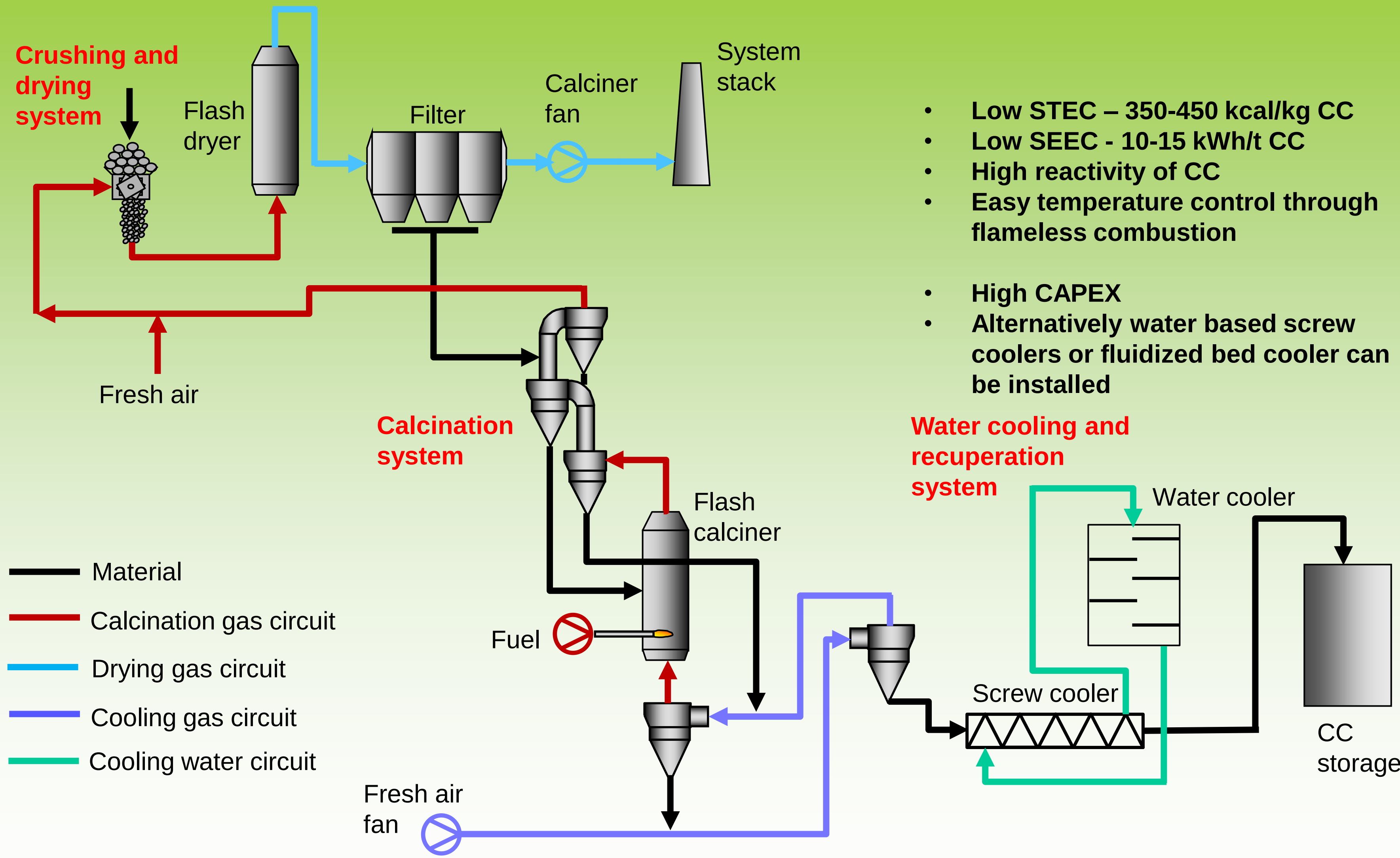
FLASH CALCINER TECHNOLOGY WITH CYCLONE COOLING SYSTEM

Low STEC – 350-450 kcal/kg CC
Low SEEC - 10-15 kWh/t CC
High reactivity of CC
Easy temperature control through flameless combustion

High CAPEX



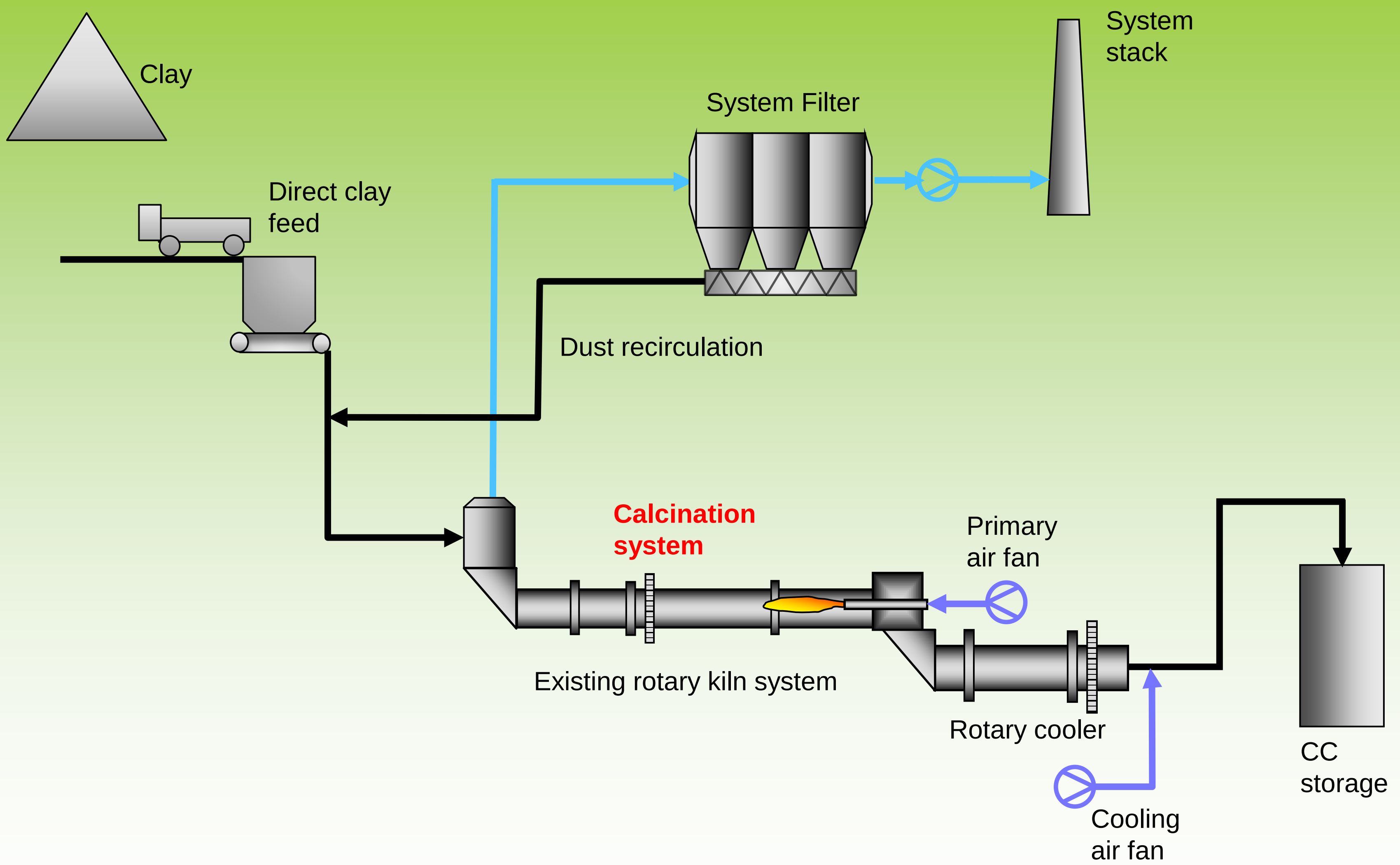
FLASH CALCINER TECHNOLOGY WITH WATER COOLING SYSTEM



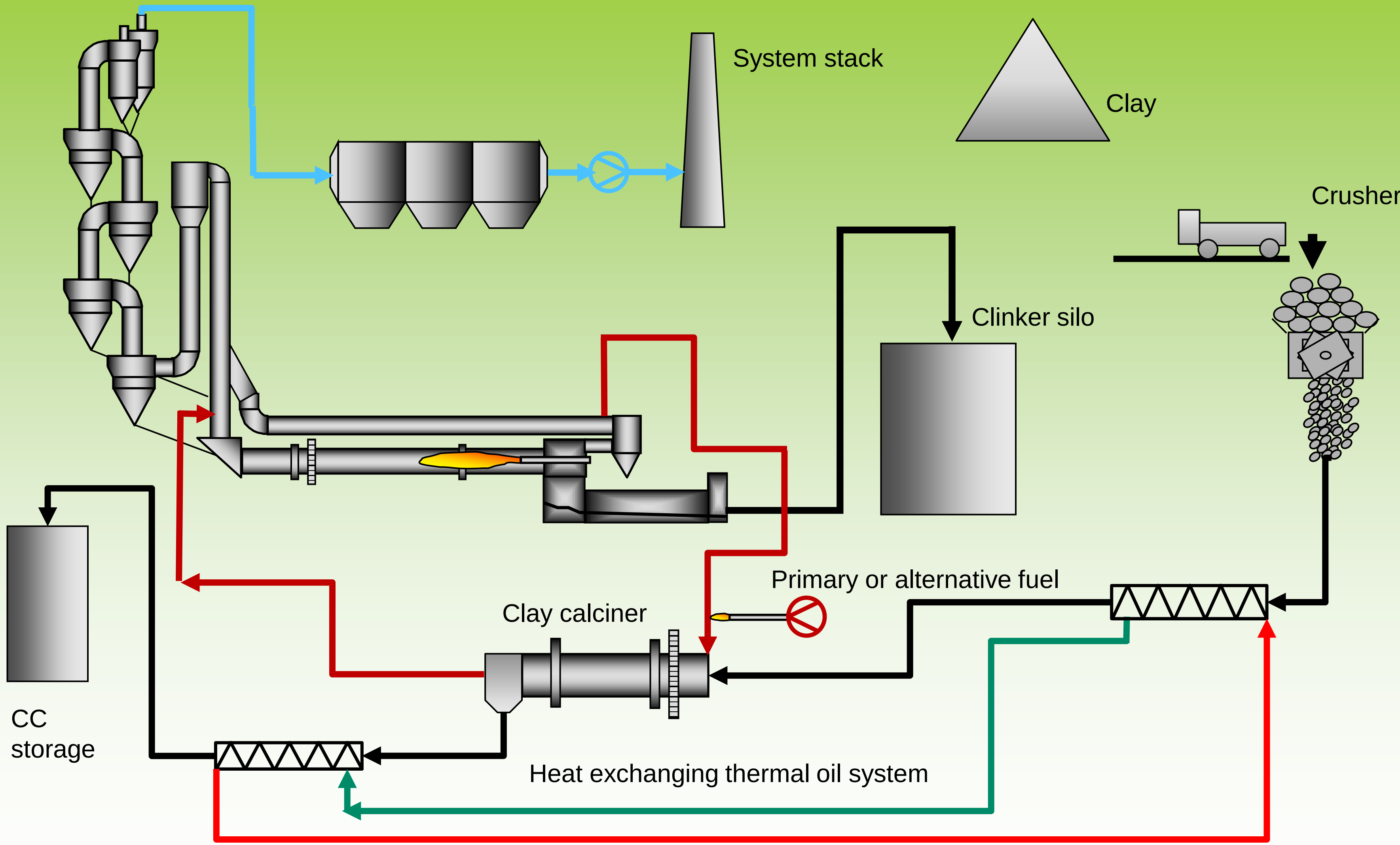
- Low STEC – 350-450 kcal/kg CC
- Low SEEC - 10-15 kWh/t CC
- High reactivity of CC
- Easy temperature control through flameless combustion

- High CAPEX
- Alternatively water based screw coolers or fluidized bed cooler can be installed

CONVERSION OF EXISTING ROTARY KILN TECHNOLOGY W/O PREHEATER



INTEGRATION OF CALCINED CLAY SYSTEM INTO EXISTING CLINKERIZATION LINE



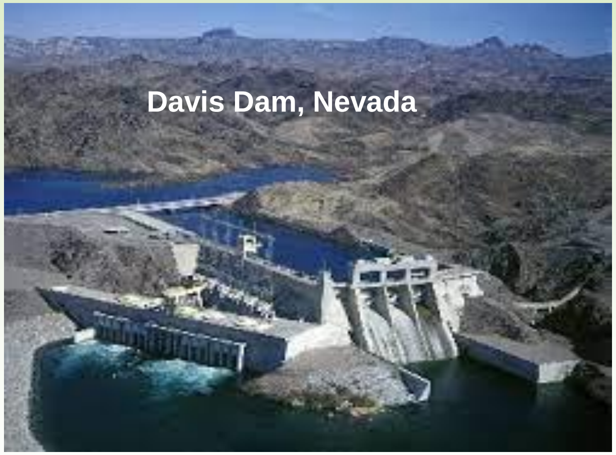
LC³ A NEW NAME FOR AN OLD PRODUCT

- LC³ is not a new product. It was widely used in US for prominent buildings with excellent performance.
- Only modern manufacturing technology is applied.
- This results in significant differences on CAPEX and OPEX figures.

Examples of application/performance	Construction	Material
Golden Gate Bridge	1933-1937	Calcined Montarray shale
Davis Dam	1950	Calcined clays and shales
Bonneville Dam Spillway	1933-1937	Calcined pozzolan
Oakland Bay Bridge	1933	Calcined Montarray shale

The main features of a LC³ cement compared to an OPC (EN 197 Cem I) are:

- Higher resistance against chloride penetration.
- Better resistance to sulfate attacks and alkali-silica reactions.
- Comparable slightly reduced workability, marginally lower early strength (<2 day), but comparable or even higher late strength (7 and >28 day).



EXAMPLE: CAPEX FLASH CALCINER VS DUO ROTARY KILN

Position	Dual Rotary Kiln Inv. [USD 000]	Flash Calciner Inv. [USD 000]
Land & Concessions	0	0
Civil Works	6’800	8’321
Equipment	13’708	15’512
Spare Parts	525	622
Freight & Transport Ins.	854	818
Erection & Installation	2’850	5’913
Pre-Production Costs	2’702	2’800
Engineering & Supervision	923	3’113
Project Total	**28’362**	**37’098**
Project Contingency	2’836	3’710
Project Financing Cost	1’702	2’226
Working Capital	0	0
Project Price Escalation	0	0
Project Investment clay calciner	**32’900**	**43’034**

FC/DRK – STEC 1700/2300 KJ/KG·CC @8.54 USD/GJ, SEEC 13/25 Kwh/t·CC @0.04 USD/Kwh, 15 FTE

- **Greenfield CAPEX 60-80 USD/t·CC. Duo-rotary Kiln a simpler installation with ~75% of CAPEX requirement vs. a Flash Calciner.**
- **Both rotary kiln & flash calciner products require post-calcination grinding to transition to LC_3.**
- **Flash calciners have enhanced product quality & control i.e. for equivalent cement product performance lower grade Kaolin or 3-5% lower clinker are likely with flash calciners vs dual rotary kiln calciners.**

- **Selection of Calciner Type is based on site specific technical and financial situations. Both applications, including hybrid solutions, will be implemented in the industry**

EXAMPLE: OPEX FLASH CALCINER VS DUO ROTARY KILN

		Duo-Rotary Kiln	Flash Calciner
Variable Cost	USD/T CC	24.1	17.0
Fixed Cost	USD/T CC	2.4	2.2
	Total	**26.5**	**19.2**

THANK YOU FOR YOUR KIND ATTENTION

I AM LOOKING FORWARD TO ANSWER YOUR QUESTIONS