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Contents

Editorial

On November 9th, 1989 I was living in Hamburg. It was the day when the wall between East and West Germany fell. I remember thousands of people in "Trabant" cars came to Hamburg and everybody was excited and celebrating parties. What Germans in the east and west had come to regard as almost impossible now happens: under pressure exerted by its own population, the (German Democratic Republic) GDR opens the border crossing points to the west.

The era of German division came to an end. The road to German unification required the consent of the four victorious powers of the Second World War: the United States, the Soviet Union, France and the United Kingdom consult with the two German states on the arrangements in the Two Plus Four talks.

The Two Plus Four Agreement was signed in Moscow on 12th September 1990. United Germany has gained full sovereignty and the Allies territorial rights end on 3rd October 1990. All borders not only in Europe were removed and the world moved closer together.
The Berlin "Mauer" Fall was the end of the cold war and nobody could even imagine, what happens now in Ukraine.

Now everybody wakes up; billions of euros will be invested in weapons and armies; trade restrictions are implemented. Share prices on stock exchanges around the world are collapsing, fossil fuel prices reach an all-time high. The energy price hike is also easy to figure out by looking at our invoices for energy consumption in our Combined Heat and Power (CHP) plant. In 2021, we paid 23€ per MWh of natural gas to supply heat and electricity to our "Blue River Recycling" plant located in the port of Papenburg in Germany. Now the utility company charges 150€ per MWh of natural gas.

When I wrote the first "Editorial" just before the inhuman attack on Ukraine I wanted to discuss the cost of climate change. I never thought about such massive fossil fuel price increase due to a war in our neighbourhood. Let's hope that the war in Ukraine will end soon. However, it shows us, that we need to be more independent from fossil fuels. So alternative fuels are not only a climate friendly energy source they are also a locally available energy source which makes us more independent from imports of fossil fuels.

In the CPM at hand, we are continuing our article series about fire protection in co-processing and waste management facilities, and Dr. Diller discusses the potential of hydrogen usage in clinker production. The article "Informal Waste Sector" shows possibilities to involve waste scavengers (who you find all over the world, even in Europe) in a sustainable waste management system. A lot of news on alternative fuels, good tidings about our company activities will round up our magazine. Enjoy the read of the first edition of co-processing magazine this year.

Dirk Lechtenberg
Managing Director
MVW Lechtenberg & Partner

Let's hope that the war in Ukraine will end soon. However, it shows us that we need to be more independent from fossil fuels

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Hydrogen – the Hottest Topic in Cement Manufacturing

By Dr. Hansjörg Diller, MVW Lechtenberg & Partner

The cement sector has been facing significant challenges in its efforts to achieve carbon neutrality. Nearly half of CO_2 emissions from cement production is caused by the calcination of the raw materials, which is mainly limestone. Combustion of fuels for firing the kiln accounts for roughly 40% of the total CO_2 emissions. There are several pathways in mitigating fossil CO_2 emissions, for instance substituting fossil fuels by waste-derived fuels as much as possible, reducing the clinker factor of cement, or carbon capture and storage.

Whilst waste-derived fuels could provide up to nearly 100% of the thermal energy a kiln requires, the full substitution of fossil fuels with truly sustainable biomass is a technical challenge due to the lower calorific value of most organic materials. Moreover, it is expected that the availability of biomass for cement production will be constrained by competing demands from other industrial sectors, for instance, power generation. However, even when using waste-derived fuels in clinker manufacturing, still fossil-derived CO_2 is being released into the atmosphere.

Using hydrogen instead of any carbon-based fuel (coal, gas, waste-derived, biomass) in clinker manufacturing seems to be a compelling and intriguing idea, for a bunch of reasons:

- The calorific value of hydrogen by weight is more than four times of coal, namely 120 MJ/kg [1].

- Hydrogen firing has a higher stoichiometric adiabatic flame temperature of 2,182°C, while natural gas has an adiabatic flame temperature of 1,937°C (both with air as oxidiser) [2]. Thus, hydrogen firing produces a higher temperature than the regular coal-fired kiln burner (around 2000°C).

Moreover, burning hydrogen produces only water as a combustion product which would leave the chimney as white plumes. Although water vapour is by far the most important contributor to the greenhouse effect owing to its large concentration in the air and strong absorbing effect on long-wavelength radiation, its lifetime in the atmosphere is only some 9 days [3]. On the other hand, the greenhouse gas CO_2 is durable. It stays in the atmosphere for around 100 to 150 years [3]. So, hydrogen firing does not generate any CO_2 emissions from combustion.

Having said this, the question is suggested: Why do not switch immediately from any carbon-based fuel to hydrogen for firing clinker kilns?

Figure 1: *The vision: Only water vapour leaves the stack of a cement plant in the future (Source: MVW).*

Interestingly, there's already a patent application from Heidelberg Cement, issued in 2017, dealing with the use of hydrogen as fuel in a cement plant [4]. Recent developments show that hydrogen firing in cement plants is a hot topic (no pun intend-

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ed). According to [6] these developments follow the awarding of UK government funding in February 2020 to support a pilot project into studying a mix of hydrogen and biomass fuels at Hanson Cement's Ribblesdale integrated plant. More recently, in October 2021, the company has released a brief note [8]. It reads: Their kiln has been "successfully operated using a net zero fuel mix as part of a world-first demonstration using hydrogen technology". They have "successfully implemented a mix of 100 percent climate-neutral fuels including hydrogen for commercial scale cement manufacture for the very first time". "The fuel switching trial has used 'grey' hydrogen as a proof of concept, which can be substituted for 'green' hydrogen in the future. At a 100% climate-neutral mix, the proportion of fuels in the cement kiln was approximately 39% hydrogen, 12% meat and bone meal (MBM) and 49% glycerine." [8]. Of course, other cement players are actively pursuing such a strategy. For instance, Mexican-based giant Cemex has executed initial trials of hydrogen technology at their Alicante cement plant in Spain in July 2019. It quickly turned out that hydrogen is a "lever to significantly reduce CO_2 emissions. The technology was installed in 2020 in all cement plants in Europe. In 2021, Cemex will roll this out to substantially all its global operations" [9].

Gee, this is good news, however, simply switching any carbon fuel to hydrogen is not a piece of cake.

Combustion and radiation properties of hydrogen differ significantly from those of conventional fuels being used in the cement industry. Although hydrogen flames are very hot and, therefore, are used in oxyhydrogen torches for cutting and welding metals, the flame emits limited infrared (IR) radiation. Therefore, it is colourless, nearly invisible. This is very different from coal, gas or oil flames.

Since the burning process in the rotary kiln relies on radiant heat transfer to the clinker, a pure hydrogen flame, although being high in temperature, will not suffice to cook the clinker. To sustain the required heat transfer via radiation a certain portion of carbon-based fuel must be present when firing hydrogen in a clinker kiln. The feasibility study [5] reads: "Mixing hydrogen with other materials/elements could be a solution to increase heat radiation (flame colouring). Clinker dust or calcined kiln inlet dust could be considered."

Moreover, given the higher temperature of a hydrogen flame, the formation of NOx can increase. However, this might be overcome with a specially designed burner [5].

There's a great deal of research and test works going on around in this sector. Many technical hurdles in co-firing hydrogen need to be overcome, as well as in the generation of "green" hydrogen, transport and storage. The prospects of co-firing hydrogen in clinker kilns are really fascinating, and I would like to look to the future when an industry has managed to overcome all technical and financial obstacles that have been placed in the path.

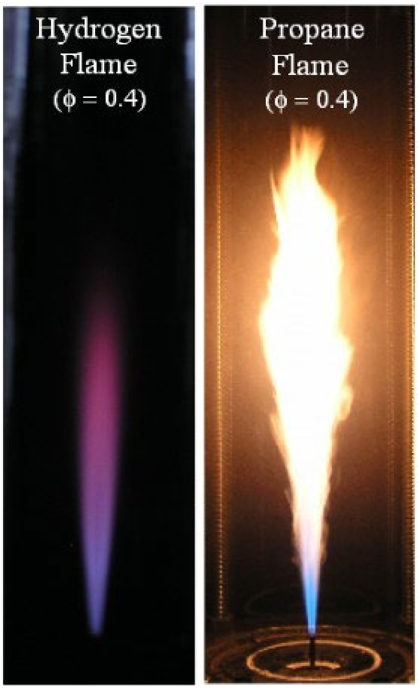

Figure 2: *The differences between hydrogen flame (left) and propane flame (right). Each flame is visible and luminous. The flame of hydrogen is primarily bluish, whereas the propane flame is bluish in a slender region in the near field and has a large yellowish region in the far field [13].*

Figure 3: *The typical kiln burner flame of highly luminous reddish-orange colour (source: MVW Lechtenberg).*

Hydrogen in Cement Industry

Generation of Hydrogen

One might think about steam reforming of natural gas with water vapour, which is a technical process being widely used in many industries to obtain hydrogen. However, this route is a dead end, for this process relies on fossil fuel.

The usual way to generate "green" hydrogen is from the electrolysis of water. To obtain 1 kg of hydrogen, around 56 kWh of electricity in the form of direct circuit is needed [7]. Considering the calorific value of hydrogen, which is 120 MJ/kg (see above), which is 33.3 kWh per kg, the energy efficiency of generating hydrogen from electrolysis is 60%. It stands to reason that when using hydrogen instead of any carbon-based fuel in a kiln, this hydrogen has to be obtained from renewable energy, like solar or hydropower, otherwise it is a deceptive packaging. As a side effect, oxygen is obtained, which can be deployed in many applications.

Trying to Look Ahead

Let's do some theoretical exercises. We have a look at an exemplary cement plant of 5,000 tonnes clinker per day (1.65 million tonnes per year). We assume a specific heat consumption of 800 kcal/kg, and coal as regular fuel. With a net calorific value of 6,400 kcal/kg, this factory would consume 206,250 tonnes of coal per year. Considering the default CO_2 emission factor from Intergovernmental Panel on Climate Change (IPCC), which is 96 kg CO_2 per gigajoule [10], this cement plant emits an annual 530,551 tonnes of fossil CO_2 from coal. This number does not include, of course, the CO_2 emissions from calcination of the raw material. Table 1 shows the summarised figures of this baseline scenario.

Clinker production	1,650,000	t/yr
	5,000	t/day
Specific heat consumption	800	kcal/kg cli
Coal consumption	206,250	t/yr
Default CO_2 emission factor of coal	96	kg CO_2 / GJ
CO_2 from coal	530,551	t/yr

***Table 1**: Basic assumptions of a typical clinker kiln (baseline scenario).*

Now, let's assume that this cement plant uses hydrogen for co-firing. We have modelled the following scenarios: 10%; 30%; 40%; 60% thermal substitution rate, and compared them against the basic assumptions. In these scenarios we trust that, based on recent achievements [8], 40% can be achieved easily, and future developments can most probably boost this rate to 60% at least. The outcome of the computations is displayed in Figure 4 and Figure 5.

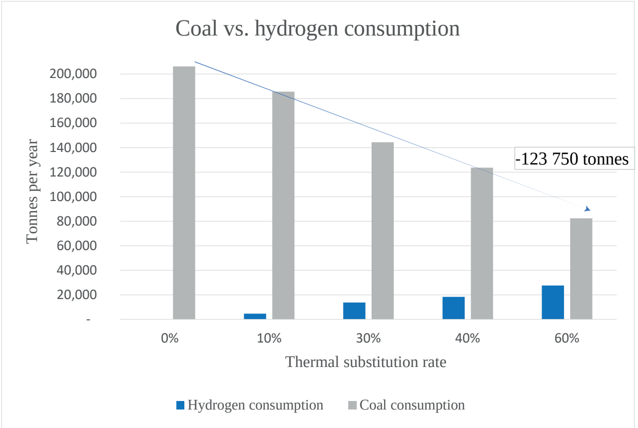

***Figure 4:** Consumption of coal and hydrogen in connection with thermal substitution rates.*

The chart reads: There's a linear trend in reducing coal while using increasing increments of hydrogen. When co-firing up to 27,633 tonnes of hydrogen (this reflects the 60% thermal substitution rate), up to 123,750 tonnes of coal – or, in other words, up to 60 % of the original baseline consumption - can be saved.

At the same time, up to 318,331 tonnes of coal-derived CO_2 (or 60% of the original baseline emission) can be mitigated (see Figure 5).

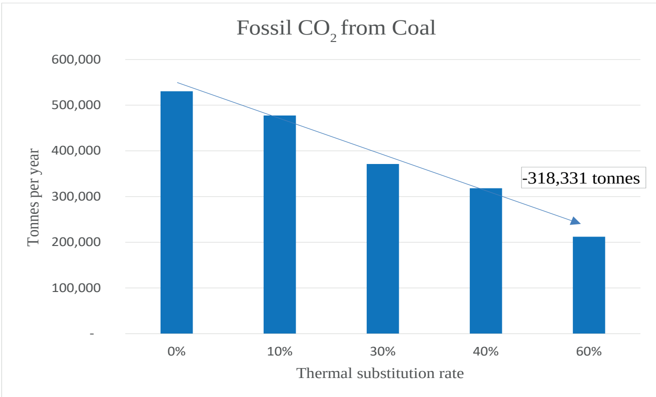

***Figure 5**: Reduction of coal-derived CO_2 when co-firing increasing portions of hydrogen.*

And now, I dare to take a look at the global clinker production capacity, which is around 3.7 billion tonnes [11]. For the sake of simplification, we assume that all kilns are fired with coal. Then, with a 60% thermal substitution rate, 62 million tonnes of hydrogen will save 277.5 million tonnes of coal, and mitigate 713.8 million tonnes of CO_2. This huge volume is close to the CO_2 emissions of Iran in 2020 [12].

How Can Hydrogen be Obtained

Now, we should shed light on the raw material and energy consumption for generating the required hydrogen. First of all, water is required to generate hydrogen through electroly-

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sis. The next table shows the required amounts of water in our substitution scenarios, and, in addition to this, also the required electrical energy.

Thermal substitution	Hydrogen consumption	Volume of water required	Volume of oxygen produced	Electricity for electrolysis	
%	t/yr	t/yr (m³/yr)	t/yr	GWh	kWh per tonne of clinker
0%	-				
10%	4,605	41,449	36,844	258	156
30%	13,816	124,348	110,532	774	469
40%	18,422	165,797	147,375	1,032	625
60%	27,633	248,696	221,063	1,547	938

Table 2*: Required volumes of water and electricity to generate hydrogen, which is used in the substitution scenarios, and 1.65 million tonnes clinker production.*

When looking at the 60% scenario, nearly 250 kilo tonnes (or 250 million litres) of water would be required for electrolysis. Around 1 547 GWh of electrical energy would be required to obtain 27 633 tonnes of hydrogen. At the same time, 221 063 tonnes of oxygen would be obtained.

The electrical energy of one thousand five hundred gigawatt hours to generate hydrogen is a huge number and not to be sneezed at. The specific energy consumption – with a hydrogen share of 60% - would be around 938 kWh per tonne of clinker. To recap: Electrical energy consumption of an integrated cement plant is in the region of 100 kWh per tonne of cement! So, the increasing utilisation of hydrogen generates an appetite for electrical energy. The question arises: How to satisfy the hunger for much more electrical energy? There is no doubt about it: The electrical energy for the electrolysis of water has to be "green" in order to get zero net emissions. We can take advantage of the energy nature provides us free of charge. Let's have a look at two of such energy sources and do another exercise.

Blowin' in the Wind

Wind turbines provide green electrical energy. A typical onshore wind turbine has a power of around 2.5-3 MW, and offshore wind turbines have a power of around 3.6 MW [14]. The generation of electricity depends on the wind speed. Let's assume an annual average wind speed of 6.5 m/s, a 3.5 MW wind turbine would deliver 8,816 MWh [15]. Since electrolysis of water requires direct current (DC), but wind turbines generate alternating current (AC), the latter has to be rectified. If we consider a 10% substitution rate in our clinker kiln, we'd need twenty six 3.5 MW wind turbines to generate sufficient green electrical energy to generate 4 605 tonnes of hydrogen. With a substitution rate of 60%, we'd need 152 wind turbines (Table 3).

Thermal substitution rate	Required hydrogen	Electricity for electrolysis	At wind speed 6,5 m/s: No. of wind turbines of 3.5 MW power
0%			
10%	4,605 t/yr	258 GWh	26
30%	13,816 t/yr	774 GWh	76
40%	18,422 t/yr	1,032 GWh	102
60%	27,633 t/yr	1,547 GWh	152

Table 3*: Required number of 3.5 MW wind turbines with increasing utilisation of hydrogen.*

A 3.5 MW wind turbine has a diameter of 82 m, and tower heights can be up to around 138 m [15]. A wind turbine is most effective when it operates in a steady, smooth, unchanging and uninterrupted flow of air. Sufficient spacing has to be observed. According to a rule of thumb, wind turbines should be spaced in a 5D x 10D grid, with D = diameter of rotor [16]. A single turbine would require around 33.6 hectares, and 152 turbines would result in a "turbine forest" of 51 km², around one and a half times the area of Dubai. This is merely a back on the envelope calculation, but sufficient to get a rough idea about the required space for one cement plant.

Let's use these results about our exemplary kiln to make a hypothesis about the global clinker production and its requirements on electricity for obtaining hydrogen. For the sake of simplicity, we focus on a 60% thermal substitution in global clinker production, which would consume 62 million tonnes of hydrogen. To obtain this volume, 3.47 million GWh from 340, 000 wind turbines of 3.5 MW each will be needed. Let's try to imagine what will be the required area to accommodate these wind turbines: We'd need 114,218 km², which is slightly more than the area of Honduras.

Solar Power

Sunlight does not only provide us with light and warmth but also with energy. Solar power reaching the earth's surface is roughly 86 quadrillion watts. The total energy demand of mankind is roughly 160 quadrillion watt-hours per year, which is equal to a power of 18.2 trillion watts. This means that we receive about 4,750 times more energy from the sun than we currently use [3].

The irradiated energy and thus the usable amount of energy depends strongly on the composition of the solar spectrum, the angle of irradiation on the earth's surface and the duration of sunshine. Depending on the season, latitude and time of year, the irradiated energy is therefore not equally intense everywhere on earth. In central Europe, the radiation energy is around 1,000 kWh per square metre, while the intensity in the Sahara is around 2,350 kWh per square metre or more.

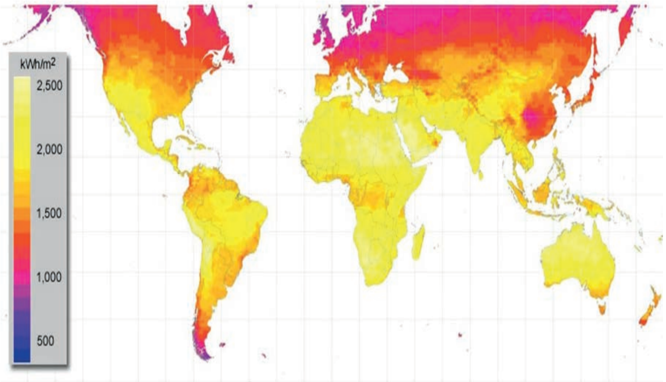

Figure 6: *Yearly sum of global irradiance [17].*

Solar power can be generated by photovoltaic cells (PV) or concentrated solar power (CSP). For the following considerations we'll focus only on PV. Assuming an average annual irradiation of 1500 kWh per square metre and, and an efficiency of PV panels of 15%, we'd obtain the required panel areas as follows:

Thermal substitution rate	Required hydrogen	Electricity for electrolysis	Required PV panels
0%			
10%	4,605 t/yr	258 GWh	1.5 km²
30%	13,816 t/yr	774 GWh	4.6 km²
40%	18,422 t/yr	1,032 GWh	6.1 km²
60%	27,633 t/yr	1,547 GWh	9.2 km²

Table 4*: Required PV panels for generating electricity in order to obtain hydrogen through electrolysis for a 5,000 t/day clinker kiln.*

If we extrapolate the numbers to cover 60% hydrogen demand (62 million tonnes) in global clinker production, then we'd end up with 20,576 km² of solar panels, which is equivalent to the area of Israel or Slovenia.

Another possibility to produce hydrogen can be in principle achieved through biomass gasification and using methane obtained from gasification in a steam-methane reformation process. Although this conventional pathway is not quite efficient, there is further research ongoing to extract hydrogen more efficiently, and the technology readiness level is still in the initial stage. This requires another article to discuss it further.

Conclusion

I'm positive that hydrogen will play a major role in the low-carbon economy, with the versatility to provide heat and, most importantly, a huge means of decarbonisation for global clinker manufacturing.

However, many obstacles line the way towards continuous and sustainable employment of hydrogen as an alternative fuel in the cement industry, and need to be overcome. Many technical issues in the pyrosystem of rotary kilns must be solved, and a great deal of complications are connected with electrolysis of water, and supply of solar, wind or other natural power, as well as storage and transport of hydrogen.

With many constraints on inland wind power sites in crowded areas (for example sufficient separa-tion from noise-sensitive neighbours, good site access, special environment or landscape designa-tions), offshore wind parks might be the solution, or wind parks in desert regions.

The impact of PV on the landscape would be less, because PV systems have siting advantages over other technologies; for example, PV can be put on roofs. However, the alternating energy output of PV owing to local weather conditions (clouds, etc.), as well as the night-time, must be buffered in order to provide a steady current for continuous operation of the electrolysis.

The numerous hydrogen production, distribution and consumption pathways not only in the cement industry present complex trade-offs between emissions, scalability and, last but not least, for cost. The latter is still high. According to [18] average cost of green hydrogen spreads over a broad range of <2…12 EUR per kilogram. In terms of unit cost per energy it is around 2…100 EUR/GJ, which is far beyond financial viability when compared with current coal prices (roughly in the region of 5 EUR/GJ. According to Global Market Intelligence [19] cost for generating green hydrogen is most probably seen in the region of one to two USD per kilogram in the next three years, which is around 8.30…16.60 USD/GJ. I can cater to this important point only very briefly, for there are plenty of uncertainties connected with that, and my intention focuses primarily on the technical feasibilities.

I'm sure that technical and socio-economic developments will eventually pave the way for hydrogen as a sustainable alternative fuel in the cement industry. As Abbas and Akritopoulos concluded recently: "…green hydrogen win future will most-

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ly be produced on-site, using large electrolysers powered by wind and/or solar energies." And: "Future cement plants could use both O_2 and H_2 streams produced from onsite electrolyser, achieving the zero CO_2 target with substantial reduction in H_2 and O_2 production costs – a plausible solution to work on for the cement plants of 2050 and beyond." [20].

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Fact Sheet: "Spent Cell Linings" also Known as "Spent Pot Linings" as Alternative Fuel

The following article is a revised excerpt from the "Alternative Fuels and Raw Materials Handbook for the Cement and Lime Industry." – Vol. 2

Introduction

Spent cell lining is a solid waste produced in the aluminium industry during the manufacturing of aluminium metal in electrolytic cells. Originally, the electrolytic cell liners comprise graphite and carbonaceous materials, but after several years of operation, the liner materials deteriorate and must be removed from the cells [1].

After its lifetime, the cell is taken out of service for repair/reconstruction, and the carbon and refractory linings are removed. They are known as Spent Cell or Spent Pot Liner (SCL/SPL). Owing to the presence of fluoride and cyanide, SCL is listed as a hazardous waste. SCL also contains significant quantities of sodium fluoride, carbon, silicon oxide, aluminium and alumina.

The fraction which contains only the carbon is the so-called "first cut", and the fraction that contains the refractory (plus portion of carbon) is called the "second cut". When the linings are removed, they can be separated into the two fractions during the digging process or are available in a mixed form.

Figure 1: *Storage of mixed SCL in a shed - dry and ventilated (courtesy by Geof Pile, Koga Group, Australia).*

Aluminium is manufactured by the electrolysis of a molten alumina or refined from bauxite in an electrolytic cell known as a "pot" or "cell". According to [2] the procedure is called the Hall-Heroult process in honour of the two inventors. The pot is a refractory and carbon-lined steel container and the alumina is dissolved in an electrolytic bath of molten cryolite (sodium aluminium fluoride Na_3AlF_6).

The melting point of the eutectic system at 960°C is much lower than the melting point of pure bauxite (which is around 2,045°C) which makes electrolysis feasible at reasonable temperatures.

An electric current is passed through the electrolyte at low voltage (around 4 – 4.5V), but very high current (around 200kA). The current flows between carbon anodes made of petroleum coke and pitch, and the carbon liner of the pot which serves as the cathode. The chemical reaction of the reduction of alumina to metallic aluminium can be expressed by the following equation (according to [2]):

Cathode reaction: $Al_2O_3 \rightarrow 2Al + 1.5O_2$

Anode reaction: $1.5O_2 + 2C \rightarrow CO_2 + CO$

Metallic aluminium collects at the bottom of the pot. It is tapped out of the pot at daily intervals. The liberated oxygen from the alumina reacts with the anode (i.e. carbon) to obtain gaseous products. As anodes are consumed by this reaction, they have to be replaced by new ones.

Only little cryolite is consumed and needs to be added from time to time. The lifetime of a pot is up to 8 years, and a pot fails usually owing to erosion of the cathode or sidewall.

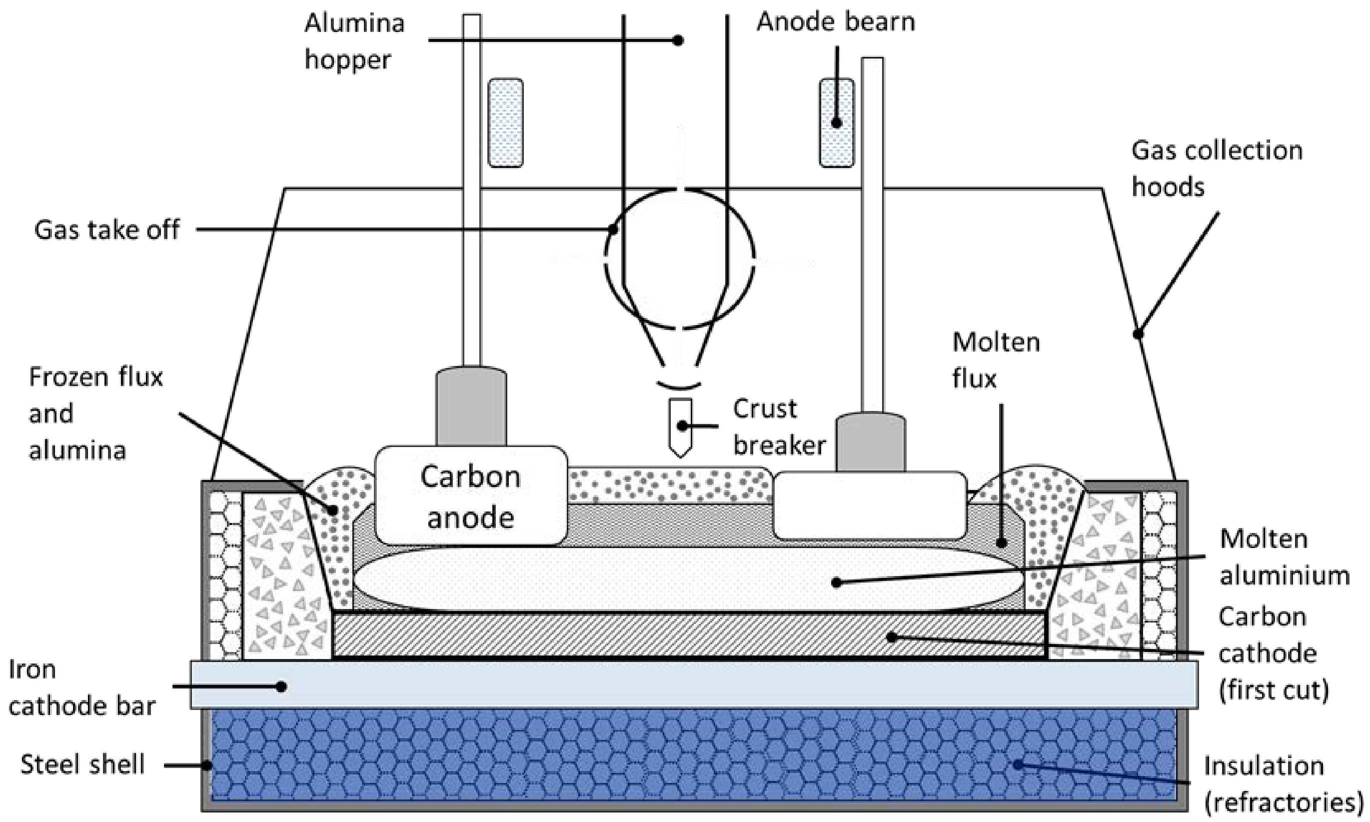

***Figure 2**: Aluminium smelting cell, according to [3].*

SCL is taken out of the used cells, as a rule, every 5 – 7 years or earlier in the case of incidents. As the mixed material is taken out with shovels, a mixed size of the material (from dusty to large lumps up to some 2m lengths) can be observed. The mixed material also contains metals (from bolting and anchoring of anodes) and metallic aluminium in percentages of up to 5%.

Quantity and Availability

According to the International Aluminium Institute, the primary aluminium smelters produced around 64 million tonnes of primary aluminium in 2018 [4]. Depending on the technology of the cell, and depending on the performance, the cells have to be refurbished every 5 to 7 years. As this is done continuously, cell by cell, approximately 1.8 – 2.5% of overall aluminium production is generated continuously in the form of spent cell linings (approx. 60 – 70 tonnes of SCL per pot every 5 – 7 years or after unscheduled stops). The list of aluminium primary smelters with their smelting/production capacities (available in the Alternative Fuels and Raw Materials Handbook, Vol. 2) [5]. In addition to this, estimations of the possible arising of SCL are provided in the Handbook, based on an average 2% of the production capacity.

Over the last few decades, the Al-production process has not seen any major changes, so the emerging of SCL from the manufacturing process can be schematically described in the figure 3.

The figure describes schematically the whole aluminium manufacturing process including formation of anodes, anodes recycling and aluminium metal and metal extraction. The discharge of SCL from the electrolytic cell is indicated.

The following table affords an overview of the composition of SCL:

Composition of SCL	
Carbon cathode	15 – 30%
Refractory slabs and bricks	30 – 40%
Vermiculite and calcium silicate board	5 – 10%
Silicon carbide bricks	2 – 5%
Absorbed catholyte (bath-like material)	15 – 25%

***Table 1**: Typical SCL composition [7].*

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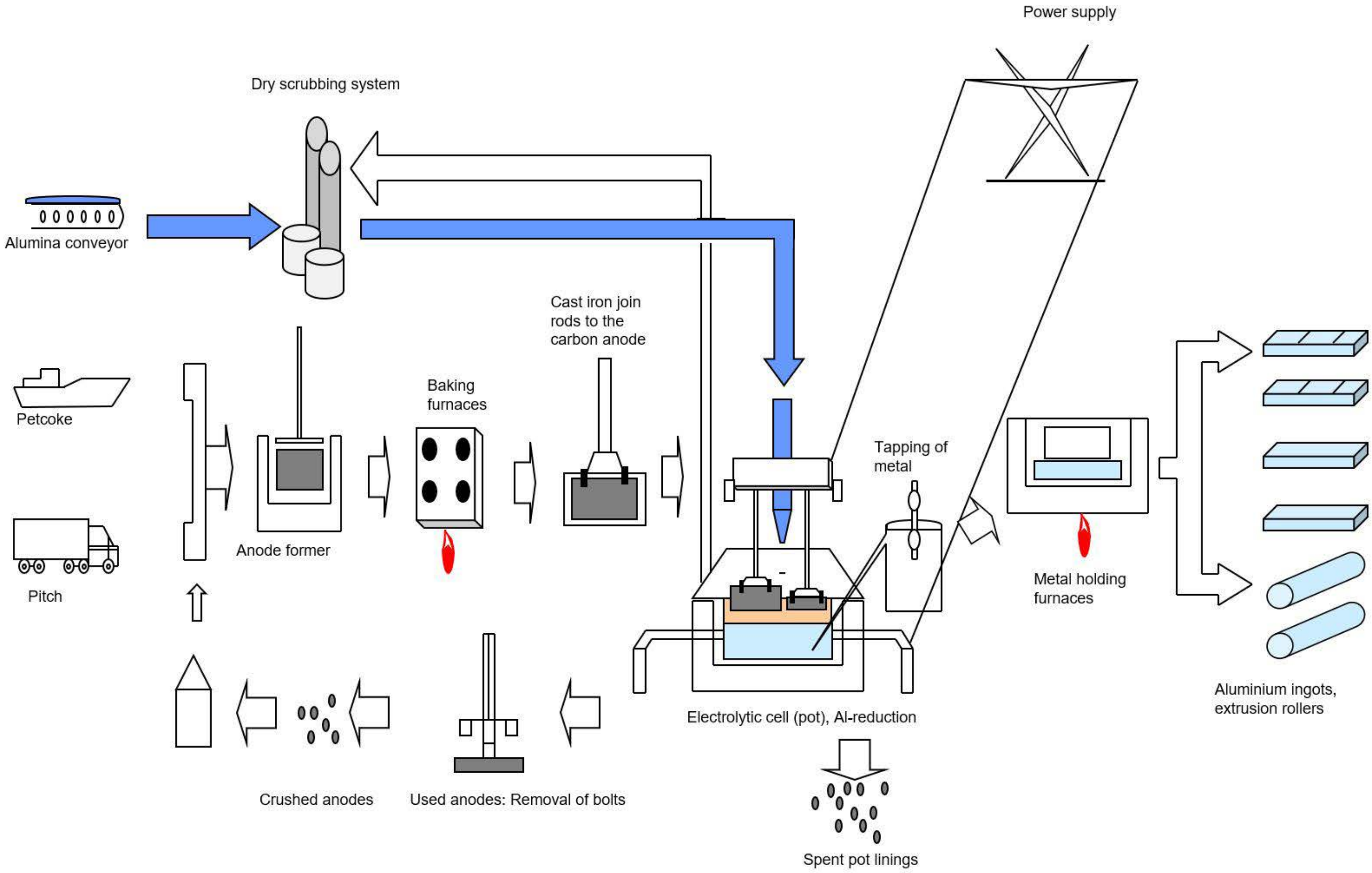

***Figure 3**: Schematic process description of aluminium manufacturing according to [6], showing also emerging SPL (SCL).*

Composition

The table 2 below affords an overview of the composition of SCL:

Composition of SCL	
Carbon cathode	15 – 30%
Refractory slabs and bricks	30 – 40%
Vermiculite and calcium silicate board	5 – 10%
Silicon carbide bricks	2 – 5%
Absorbed catholyte (bath-like material)	15 – 25%

***Table 2**: Typical SCL composition [7].*

The table 3 shows typical chemical data of SCL, accompanied by data of calorific value analyses:

Parameter	Unit	Typical value
C	%	15 – 30
Na_2O	%	15 – 18
K_2O	%	0.5 – 0.8
F	%	9 – 13
Al_2O_3	%	27 – 37
SiO_2	%	14 – 22
Fe_2O_3	%	1.5 – 3
CaO	%	1.5 – 3
S	%	0.05 – 0.15
Cl	%	0.01 – 0.04
Total cyanides (expressed as CN)	%	0.02 – 0.05
Moisture (at dispatch)	%	0.5 – 2
Net calorific value	kJ/kg	5,000 – 10,000
Chromium	ppm	20 – 100
Cobalt	ppm	20 – 80
Copper	ppm	50 – 200
Lead	ppm	10 – 20
Mercury	ppm	< 0.01
Nickel	ppm	50 – 150
Selenium	ppm	< 2
Thallium	ppm	< 0.1
Vanadium	ppm	50 – 150
Zinc	ppm	20 – 80
Antimony	ppm	0.5 – 1
Arsenic	ppm	5 – 15
Barium	ppm	50 – 200
Beryllium	ppm	4 – 8

***Table 3**: Typical chemical data of SCL (Source: MVW).*

Being abundant in aluminium and carbon, SCL features typically considerable amounts of sodium and fluorine, deriving from cryolite. SCL affords some calorific value owing to carbon residues from the cathode material.

In the Alternative Fuels and Raw Materials Handbook, Vol. 2, an overview of the ash composition and gas generation data when stored in ventilated containers including SCL hazardous characteristics can be found.

Collection and Transport

SCL is only produced at aluminium smelters. All these smelters collect their SCL waste and store it in designated storages (dry and well-ventilated storages). Storage areas, containers and/or confined spaces must be ventilated. SCL has to be kept dry in order to prevent accumulation of explosive gases (e.g. hydrogen, methane). Release of dusty SCL to the environment by leaks or spreading of dusty SCL out of the storage by vehicle traffic must be prevented. SCL must not come in contact with acidic substances (which can generate lethal gas concentrations).

SCL may be transported as bulk material in freight or sea containers or in appropriately designed trucks or rail cars. Furthermore, transport by water-proof big bags in closed but ventilated containers is possible.

Sea containers shall be used for transportation by ships. Containers and covers must be adequate to maintain the material in a dry state. Closed shipping containers must be vented.

Containers, rail cars or trucks should be dedicated to SCL transportation. They must be thoroughly cleaned prior to use for other materials in order to prevent chemical reactions which can provoke dangerous gas evolution. Shipments have to be labelled with the so-called UN number, which is 3170. SCL can only be processed for thermal utilisation if finely-ground and with a defined grain size, hence special health and safety measures have to be implemented (e.g. dedusting, ATEX requirements). Ground SCL (less than 10mm) has a density – depending on the carbon content – of approximately 850 – 900kg/m^3.

Challenges and Potential Benefits of Co-processing SCL in Various Industrial Subsectors:

Owing to the high content of hazardous substances (e.g. cyanides) and the highly reactive material, SCL is either neutralised by calcination processes with temperatures above 600°C and then landfilled in designated hazardous waste landfill sites or processed into a fuel or raw material substitute for the cement industry, foundries or steel plants. In the last years, the insulation industry has used increased volumes for the production of stone wool. The company Rockwool in Germany has developed a concept to use spent cell liners as substitute raw material and fuel. In 1988, American Rockwool conducted a few test programs in their facility to measure emissions of particulate matter, SO_2 and fluorides by feeding SPL by replacing coke on a pound-per-pound basis in their cupola furnace [8]. Emissions were determined for three different charges or conditions described in the table 4.

Charge (1 lb)	Condition A	Condition B	Condition D
SPL	0	210	450
Lime	0	0	50
Coke	385	260	140
Duquesne	1300	1300	1300
Trap rock	1100	1100	1100
Steel slag	400	400	400
Tennessee slag	400	400	400
Avg. No. charges/hr	3.5	3.4	3.0

***Table 4**: Average charge makeup per cupola furnace in American Rockwool facility [8].*

The emissions results obtained from the conducted test programs by American Rockwool is summarised in table 5:

Condition	Particulate matter	Fluoride	Sulphur dioxide
A	1.2	0.73	104.7
B	1.8	7.84	95.2
D	1.8	5.10	57.1

***Table 5**: Average total emissions for cupola furnace in American Rockwool facility [8].The U. S. Patent 4,822,388 from 1989 also describes a process for the use of SCL in mineral wool cupolas [9].*

[10] provides a review of the use of SCL in the pig iron industry both as fuel and for decreasing the slag viscosity. SPL is added in amounts of between 5 – 25 kg/t pig iron and the SCL refractory part and bath material dissolves in the slag. The slag is designed so that any leaching of environmentally dangerous elements is minimised. For the manufacture of special steels only the use of carbon-rich first cut SPL material is proposed. The refractory-rich 2nd cut of SCL can be used in the production of aluminium silicon alloys, furthermore in foam-silicate manufacture. Alouette Aluminium Smelter in Canada uses SCL refractory material for the manufacture of special movable concrete blocks, used for bordering highways, but also used as removable walls for rapid access to buildings' basements.

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Owner	Process	Goal	Pilot	Demo plant	Industrial	Status
RTA (Pechiney)	SPLIT	Industrial waste	x	x		Stopped
Outotec (Lurgi)	Gasification	AlF_3 and industrial waste	x	x		Stopped
Nova PB	Rotary kiln	Industrial waste	x	x		Stopped
Alcoa (Alcoa of Australia)	Ausmelt	AlF_3 and industrial waste	x	x		Stopped
Alcoa (Elkem)	Arc furnace	Recovery pig iron and industrial waste				Stopped
RT (Comalco)	COMTOR	Bayer liquor/industrial waste			x	In operation
Ormet/Alcoa	VORTEC	AlF_3 and industrial waste	x			Stopped
Rockwool (Germany)	Mineral wool manufacturing	In the process of manufacturing mineral wool, as a partial substitute for coke			x	In operation
Regain	Rotary kiln	Partially detoxified SPL			x	
Chalco Zhengzhou	Rotary kiln	Industrial waste	x			
Chalco Pingguo	Rotary Kiln	Industrial waste			x	Ongoing
Alcoa (Reynolds)	Rotary Kiln	Industrial waste	x	x	x	In operation
Yichun Smelter	Flotation	Industrial waste				
Europe Community's Horizon Programme	REMOVAL	Bauxite residue with other industrial by-products, like SPL to form aluminium primary production	x			Ongoing
Elkem	Eyde Waste 2 Value	Agglomeration and high temperature reduction	x			Ongoing
RTA	LCL&L	Bayer Liquor, CaF_2 and industrial waste	x	x	x	In operation
BEFESA	Hydrometallurgy	Industrial waste			x	In operation
Weston Aluminium	Salt dross recycling	SPL			x	In operation

Table 6: *Pilot and industrial processes for treating SCL [12,13].*

Spent cell linings can be processed into kiln grade spar through the COMTOR™ process. Calcined SCL is mixed with water and lime to produce a concentrated caustic liquid stream and a solid product, Kiln Grade Spar (KGS). By treating the spent cell linings in this manner, leachable fluorides and cyanides present in the spent cell linings are removed. The solid product satisfies limits set for leachable species and could be landfilled if required [11].

Several other industrial processes are under development and pilot stage, also few have stopped. Table 6 cited from [12,13] provides a summary of processes that have progressed to the pilot stage or further.

One of the promising approaches reported is the co-processing of SPL with salt cake. The salt cake is also a by-product of the secondary aluminium industry obtained during the scrap/dross melting process. Moreover, Befesa Aluminum developed a synergy by blending salt slag with 2nd cut SPL, which minimises the energy required to operate their water leach process in order to generate Salt (a mixture of NaCl and KCL) and Paval a new term coined by Befesa (also known as BFA, Serox and BPL) depending on the location of production plants of Befesa with 630,000 t/year total capacity in four plants salt slag and SPL are valorised in Spain, Germany and the UK, a by-product appropriate for the cement or mineral wool industries [14].

In Europe, raw material supply is a challenge today which also lies in technological innovations to increase the utilisation from different industrial waste streams and metallurgical by-products. Thus, the EU is funding quite numerous funding programs for pilot projects in order to maximise the potential of different residue reuse solutions, one of them is "RemovAL" will process several by-products from the aluminium sector and from other metallurgical sectors in Europe (SiO_2 by-products, SPL, fly ash, and others) shown in figure 5 [15,16]. In this "RemovAL" project 6 innovative pilot plant studies will be carried out, in which two of them will utilise 50 t of bauxite residue to be processed in the AoG (Aluminium of Greece) pilot plant in Greece and in the ELKEM pilot plant in Norway [16].

Under the umbrella of Rio Tinto Canada, AP technology claims to find the solution through low-cost leaching and liming SPL – the technology has been coined to LCLL2 (Low Caustic Leaching and Liming) process described in figure 5 and developed in SPL treating facility of Rio Tinto's facility in Saguenay, Quebec, Canada [17].

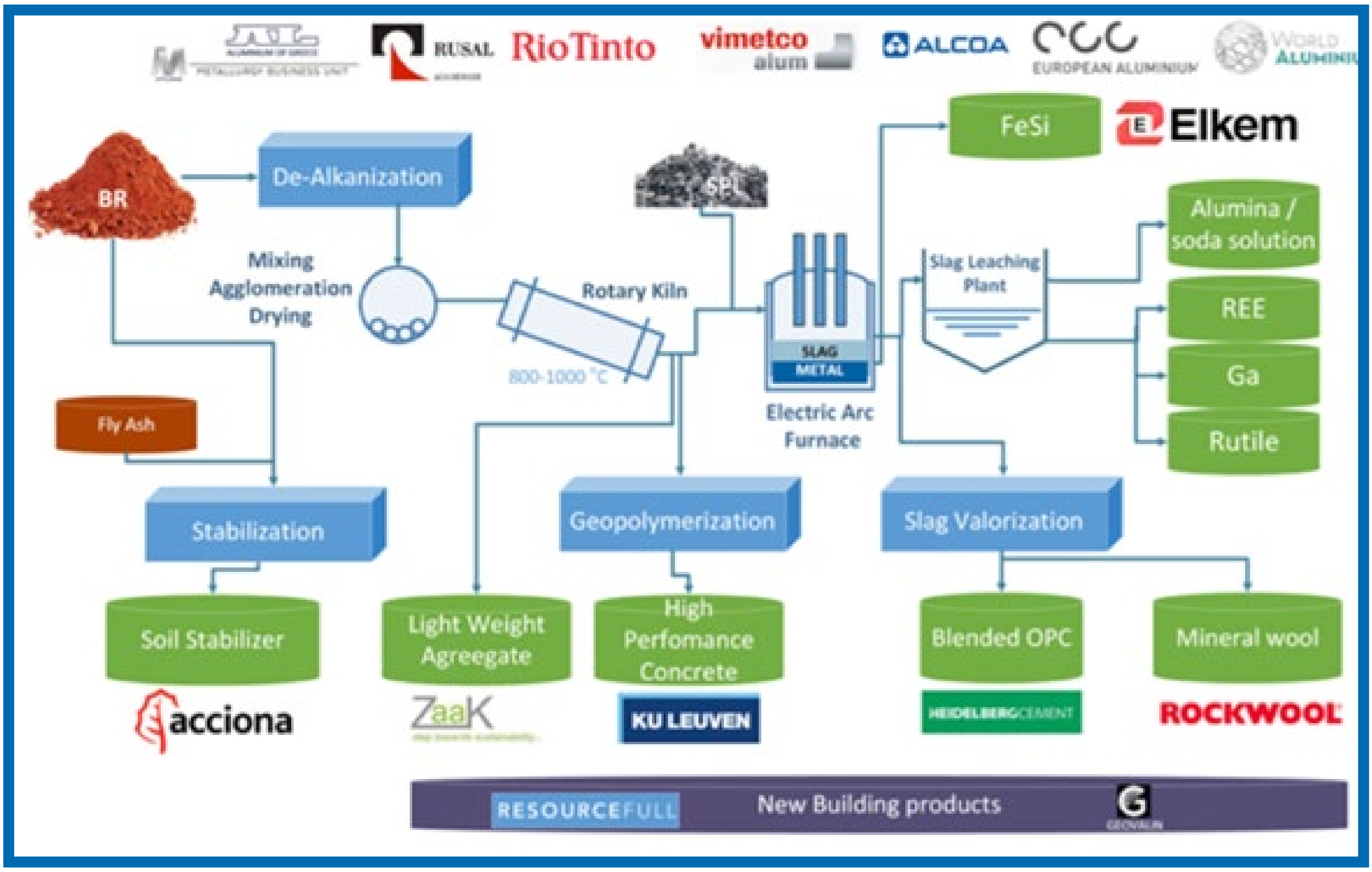

Figure 4: *Visualisation of integrated processing, which will be implemented at a pilot scale in the "RemovAL" project [15].*

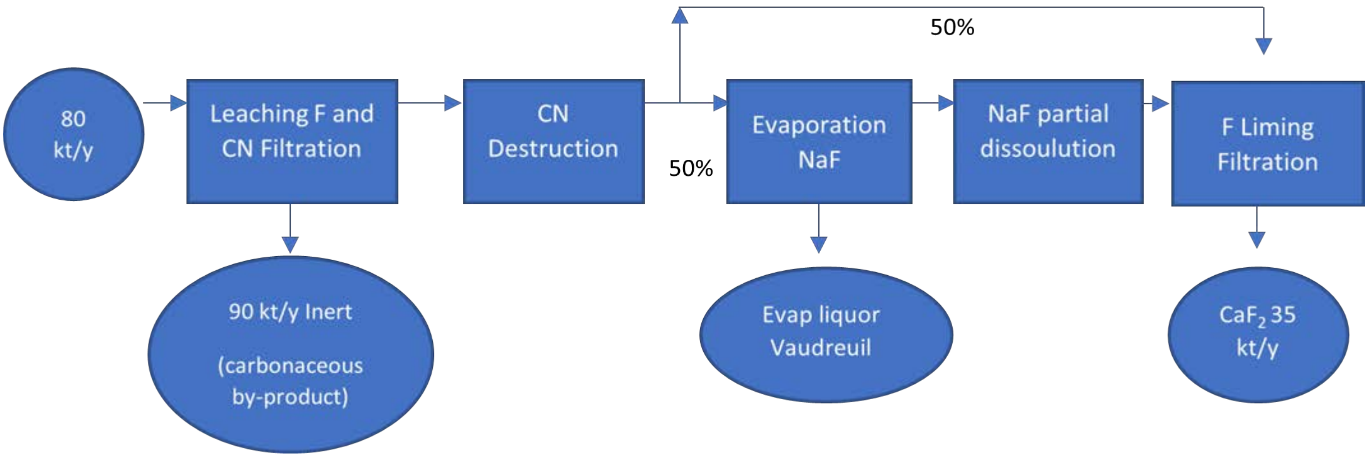

***Figure 5**: LCLL Process – Bypass of the evaporation/crystallisation and filtration of CaF_2 [17].*

UK-based firm Ultromex claims that they have developed a novel process denominated as CARBOMEX for treating SPL removing all toxic compounds, evolving no gases to the atmosphere and leaving behind no wastes; all process outputs are converted into secondary resources for use by other industrial sectors [18]. The UK based firm is seeking to deploy a small-scale commercial demonstration plant to showcase the technology and validate-economic performance.

According to [19] SPL can be used to replace carbon injections in an electric arc furnace (EAF) for steelmaking as SPL is a good carbon source, it also contains a significant amount of SiO_2 and Al_2O_3, which can restock slag with flux and influence its basicity.

Use as Alternative Fuel in a Cement Plant

For several years SCL has been used as an alternative fuel and raw material in the Australian cement industry. A classic process involves adding finely ground (< 3mm) 1st cut SCL directly at the kiln burner or mixing it with coal in the precalciner burner [7]. South African Pretoria Portland Cement has been using 2nd cut SCL for many years, com-

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mencing SCL use as a secondary material on a small scale in 2001. Other cement factories in Mozambique, Oman, Saudi Arabia, for example, use SCL through the raw material route, by dosing the material to the raw material crusher.

Since then, valuable information and data have been acquired concerning the handling, use and monitoring of that material. The results from these studies mostly confirm that cement kilns can achieve the same destruction rates for the inherent contaminants as purpose-built incinerators [20].

Fuel substitution calculation			
	Calorific value [kcal/kg]	Substitution factor CV coal	Substitution factor CV petcoke
Spent cell lining	1,200	5.08	6.83
Spent cell lining	2,390	2.55	3.43
Coal	6,100	1	--
Petcoke	8,200	--	1

Table 7: *Substitution calculation (Source: MVW).*

According to table 7 the typical range of the calorific value of SCL is 5,000 to 10,000 kJ/kg (1,200 to 2,390 kcal/kg). The range is considered in the calculation scheme by affording respective substitution factors for both values in comparison to typical coal and petcoke as regular fuels.

In order to replace one tonne of coal, between around 2.5 and 5 tonnes of SCL have to be used. The SCL portions with regard to petcoke substitution are roughly 30% higher.

The calorific value of SCL is quite low. Owing to its high inorganic content SCL actually serves as raw material rather than fuel, although indeed contributing some energy content to the rotary kiln.

SCL can also serve as fluorine-bearing material as substitute for natural fluorspar, which is used in some cement facilities as mineraliser. The next table shows the range of substitution factors if SCL is used instead of natural fluorspar. Basic data for the calculation:

Natural fluorspar (87%)	42% F
SCL (see table 8)	9 – 13% F

Raw material substitution calculation		
	% F (original matter)	Substitution factor fluoride
Fluorspar	42	1
SCL	9 – 13	4.7 – 3.2

Table 8*: Substitution calculation for SCL compared with fluorspar (Source: MVW).*

This means, one tonne of natural fluorspar (87% CaF_2) can be substituted by around 3.2 to 4.7 tonnes of SCL. As SCL contains some ammonia, it may contribute to reduction of NOx once fed into the kiln inlet, thus decreasing the needed amount of additional NOx-reducing agent in SNCR.

Biomass-CO_2-Value, Greenhouse Gases

SCL has no biogenic carbon content. The co-combustion of SCL does not save any fossil-derived carbon dioxide, thus not contributing to greenhouse gas mitigation. However, as SCL produces hydrogen if it becomes wet (e.g. humidity), the avoidance of hydrogen generation by using SCL as alternative material could be an opportunity for indirect greenhouse gas emission reduction. While molecular hydrogen (H_2) is not a direct greenhouse gas, it is assumed that it reduces hydroxide radicals and thus indirectly increase methane CH_4 and hydrofluorocarbons (HFCs) [21]. The experts' platform ESKP [22] provides another aspect on possible secondary climate effects triggered by hydrogen: If molecular hydrogen (H_2) escapes into the atmosphere, it reaches the very dry stratosphere (approx. 10 - 50 km altitude) through global transport patterns and is chemically converted into water vapour there. Water vapour is the most important greenhouse gas in the atmosphere. However, the impacts of hydrogen have not been well studied by the atmospheric science community. A review article from 2018 [23] reads: The consensus from the limited number of studies using current stratospheric ozone models is that the impacts of hydrogen on the stratospheric ozone layer are small. The best estimate of the carbon dioxide (CO_2) equivalence of hydrogen is 4.3 megatonnes of CO_2 per 1 megatonne emission of hydrogen over a 100-year time horizon, the plausible range 0 – 9.8 expresses 95% confidence. On this basis, the impact of hydrogen emissions on global climate is very unlikely to be zero and is very likely to be small and warming (positive influence).

It has to be discussed with local authorities whether hydrogen-avoidance can be recognised in a Clean Development Mechanism (CDM) scheme.

Fact Sheet

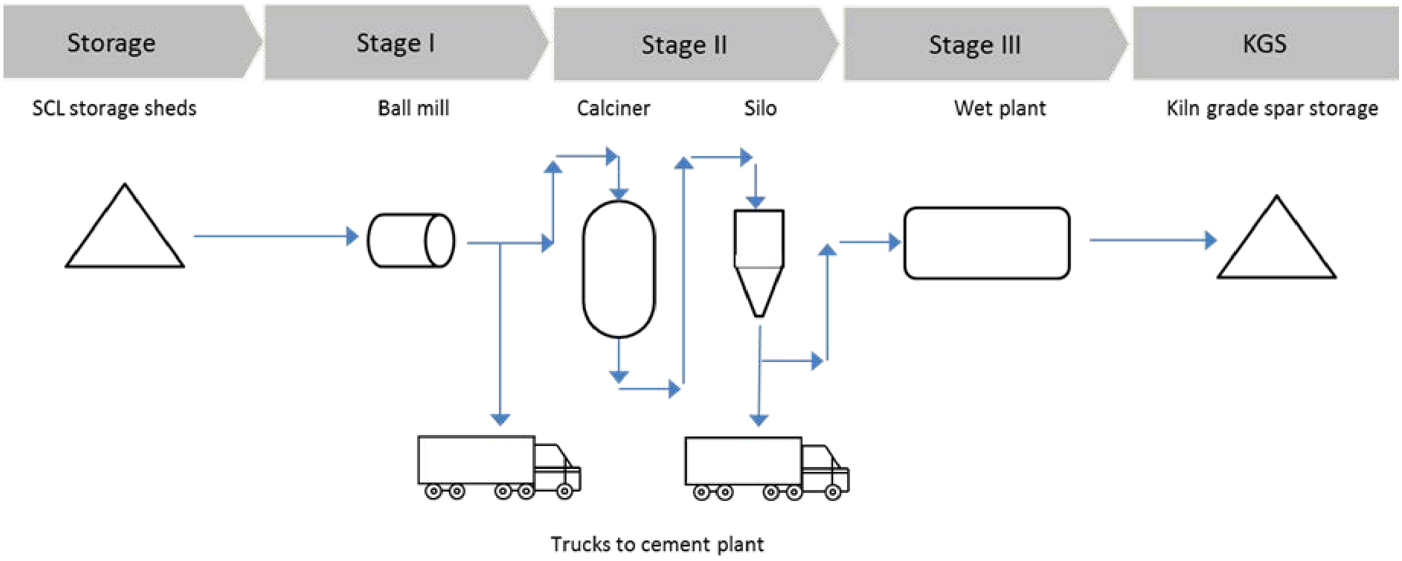

***Figure 6**: SCL treatment procedure at an Australian smelter (Source: MVW).*

Reception and Storage

Prior to use as alternative fuel in clinker kilns SCL is subject to pre-processing. The pre-processing is done at the smelter's facility. SCL from the storage is transported to the grinding facility where it is ground in a ball mill. The so-called stage I material (grain size around 60µm, assigned for kiln burner feeding) is transported by special enclosed vessels to the cement manufacturer. However, finely ground SCL develops gaseous product while handling, so SCL is subsequently thermally treated at temperatures of around 600°C. This treatment destroys gas developing compounds, thus minimising health and safety risks. The figure 6 above provides an overview of the SCL treatment.

SCL grinding to around 60µm and subsequent calcination is very costly. Therefore, it is suggested to use coarser SCL and another feeding point which is less sensitive than the kiln burner. Crushing of SCL down to less than 10mm and feeding into the backend of a clinker kiln or into the calciner at low rates (some 0.7t/h) showed the viability of this modified treatment and utilisation procedure. However, the refractory parts of SCL cannot be burned in a clinker kiln, so the unburned refractory part will be remaining in the clinker. This phenomenon does not hamper cement grinding. However, if the clinker is sold to other grinding facilities visual inspection by the customer could give rise to complaints.

For kiln back-end or calciner feeding SCL is subject to crushing and screening. The following steps comprise briefly the appropriate treatment:

- Separation of large SCL parts and foreign parts like metals (Fe, Al) by mechanical means
- Screening to less than 10mm
- Crushing of screen overflow to less than around 150 – 200mm
- Metal separation
- Screening to less than 10mm
- Final crushing of screen overflow to less than 10mm
- Intermediate storage of crushed material (silo or bulk) inside the shed
- Big bag filling

All above operations have to take place inside the SCL storage hall or shed, which should be equipped with a ventilation and de-dusting system. It is advisable to operate dustproof mobile equipment (front loader, excavator).

Packing of the crushed SCL (grain size 0 – 10mm) into big bags or silos can be done simultaneously to the processing. It is advised to fill big bags after the processing, after the finished material is degasified and with lower dust emissions, in order to avoid risk of explosion. The gas generation rate must be carefully monitored during processing and storage as well as during big bag filling.

SCL should be stored in dry and ventilated storages. It is advisable to use water-proof big bags. If the transport distance is short, storage can take place in silos (silo trucks or silo containers) as well. Please note that only designated containers and silos can be used! Possible contacts by employees involved with the unloading of big bags as well as fugitive emissions of SCL dust to the environment have to be prevented.

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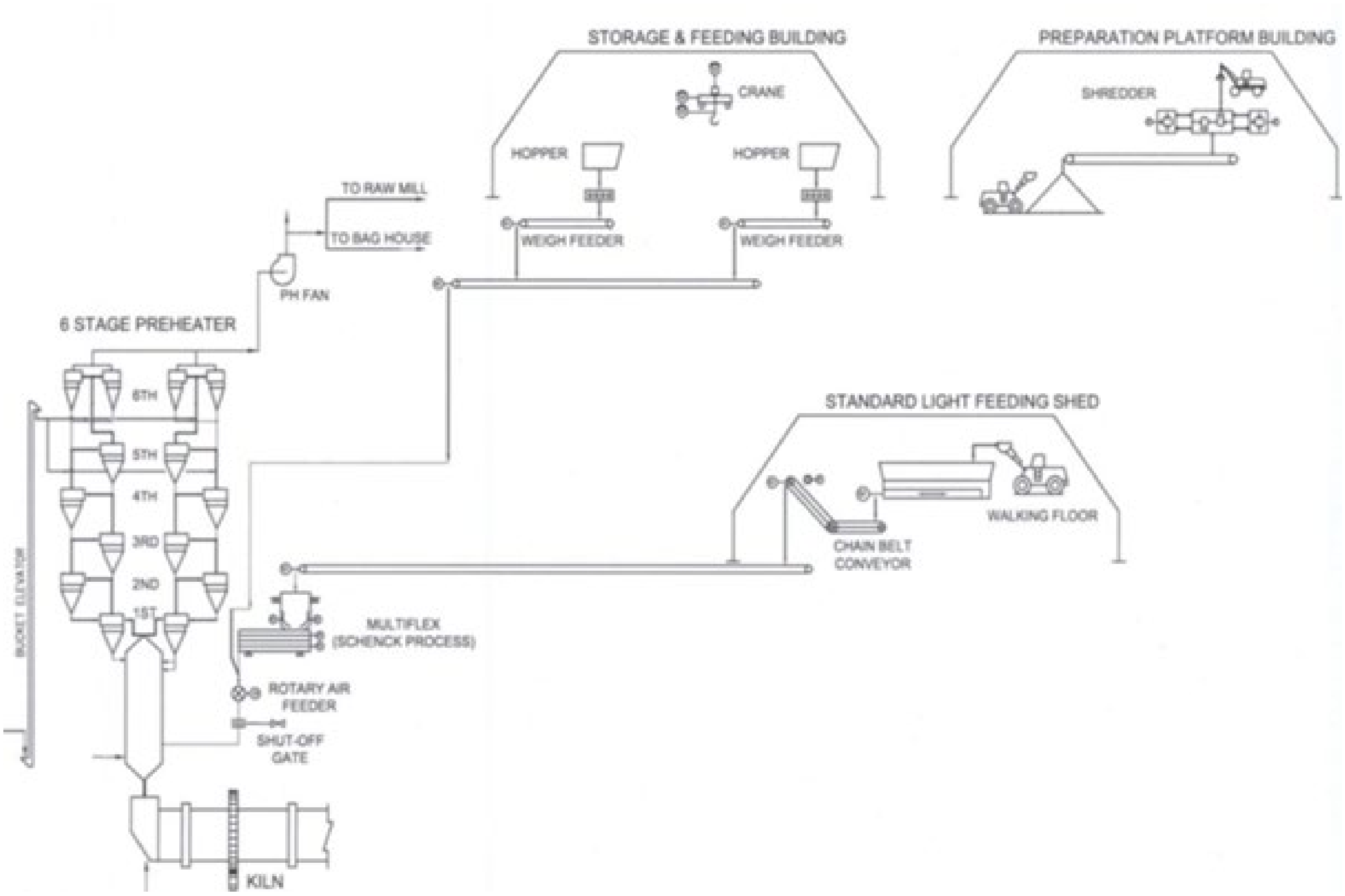

***Figure 7**: Process flowchart of ACL Bhatapara's integrated facility to co-process SPL [25].*

Dosing and Feeding Systems

In an Australian cement plant, finely ground SCL (some 60µm) passes a rotary weigher before it is pneumatically fed to the main burner. It enters the main burner through a separate channel. Along with SCL, other fuels are fed through separate channels, e.g. fuel oil or coal dust. Another possibility is SCL feeding into the kiln inlet. SPL (grain size less than around 0.15mm) feed was done using big bags that were poured into a screw feeder that directed the material to the kiln inlet. After this trial phase the feeding system was switched to a pneumatic line [24].

Moreover, feeding of SCL to the calciner is being practised. According to Geocycle 2014 [25] Indian-based ACL Bhatapara has a dedicated and integrated waste handling facility comprising the reception, storage, crushing, handling, feeding, and dosing of crushed SPL to the calciner. Figure 7 shows the process flowchart of that facility.

Some cement plants introduce 2nd cut SPL to the raw material crusher. SPL is fed gravimetrically to the raw material crusher or directly to the raw mill, and SPL then follows the usual raw material route towards the preheater. For instance, Oman-based cement manufacturer OCC has reported that they feed up to 0.35% of SPL to their raw material [26].

Quality Influence on Clinker

SCL is well known in the cement industry as an alternative fuel and raw material. SCL influences the clinker chemistry as it contains considerable amounts of fluorine, alkalis, aluminium, silica.

In particular, alkalis limit the use of SCL as AFR in a cement plant. Due to the high alkali content (in particular: sodium) of SCL the Na_2O-equivalent of the clinker will rise. The Na_2O in clinker has to be limited depending on the reactivity of the cement (the sulphate optimisation should be reviewed) or on the usage in concrete together with alkali sensitive aggregates. The mineralising effect of fluorine in SCL can reduce the clinker burning zone temperature by almost 50°C which offers twin benefits of recycling the wastes and saving thermal energy in pyro-processing. Fluoride-containing additives have a major influence on the liquid phase in a kiln, and act as a mineraliser to accelerate the formation of C_3S below the regular stability temperature. Fluorides also act as a fluxing agent and cause the liquid phase to appear at a lower temperature. Since liquid formation is essential in the formation of alite (tricalcium silicate, Ca_3SiO_5, sometimes displayed as $3CaO \cdot SiO_2$), fluorides allow the formation of alite in clinker at a lower temperature. Regardless of the appearance of the liquid phase, the activation temperature must be sufficient to form alite. Studies indicate that fluoride acts as a mineraliser and

	Model clinker composition without SCL	SCL ash composition	SCL ash input	Model clinker + SCL ash	Model clinker + SCL ash referred to 100%	Difference to original clinker
	[%]	[%]	[%]	[%]	[%]	
CaO	66.20	2.6	0.02	66.22	65.71	-0.49
SiO_2	21.45	20.5	0.16	21.61	21.44	-0.01
Al_2O_3	6.00	38.5	0.30	6.30	6.25	0.25
Fe_2O_3	2.50	2.6	0.02	2.52	2.50	0.00
K_2O	0.88	0.8	0.01	0.89	0.88	0.00
Na_2O	0.20	21	0.16	0.36	0.36	0.16
F	0.01	14.1	0.11	0.12	0.12	0.11
Rest	2.76	0.02	0.00	2.76	2.74	-0.02
Total	100.00	100.00		100.78	100.00	0.00
Lime saturation factor	96.3	2.5			95.2	-1.1
Silica module	2.52	0.50			2.45	-0.07
Alumina module	2.40	15.00			2.50	0.10
Na_2O equivalent	0.78	21.53			0.94	0.16

***Table 9**: Influence of SCR ashes on a "model" clinker (Source: MVW).*

that alite can be formed at temperatures, in practice, in the range of ~1,200°C, instead of the normal lower stability limit of 1,250°C when fluoride-additives are added to the kiln [27]. Fluoride basically has a two-fold positive effect on the kiln operation by lowering the clinkering temperature, and causing liquid to appear at a lower temperature. Lowering the clinker formation temperature results in energy saving for kiln operations since less fuel is required to elevate the burning zone of the kiln to this lower temperature. This can be especially beneficial to kilns that have feedstock that is difficult to burn. Savings of fossil fuels of up to 15% at the kiln burner were reported.

Also, the thermal strain of the kiln refractories can be decreased. On the other hand, there can be some influences on clinker (e.g. increased resistance to grindability) and cement properties (compressive strength development – less early strength, increased 7 and 28 day compressive strength) occur. Usually, the addition of calcium fluoride is dosed to the raw meal to obtain a fluoride content of approx. 0.1%, in some cases up to 0.25% in the clinker [27]. Experiences show that setting times are unacceptably long at fluorine levels greater than 0.35%. The clinker colour may shift from grey to pinkish colour. Furthermore, SCL feeding into the kiln inlet or riser duct may give rise to uncontrolled mineralisation, thus provoking built-ups in the preheater. Influences are discussed more in detail in the Fact Sheet "Calcium fluoride sludge" of the Alternative Fuels and Raw Materials Handbook, Vol. 2 [5].

Having considered all the aforementioned features of SCL one can ask for a practical utilisation rate of SCL. A simple model calculation affords an impression of the impact and substitution rate.

A virtual clinker kiln produces 100t/h, with a specific energy consumption of 850 kcal/kg clinker. SCL is used at a rate of 1t/h. Assuming an average calorific value of 1,790kcal/kg, the substitution rate achieves 2%. SCL consists of 78% inorganic material, i.e. ash. The chemical influences are shown in the table 9.

As can be clearly seen in table 9, a thermal two per cent substitution rate extends the fluorine content in clinker by a magnitude of 10. Sodium equivalent rises by 20%. These effects double while raising SCR feeding rate to 2t/h (equal to 4% substitution rate).

Considering the limitations on alkalis and fluorine, a substitution of mixed SCL of 1% to max. 3% (around 0.5 to 1.5t/h) can be achieved depending on the already used raw materials and fuels.

Last but not least the lime saturation factor of the raw mix

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should be adjusted by more limestone, for SCL reduces the LSF by around 1 point. The alumina module rises slightly by 0.1.

The influences on cement properties (setting time, compressive strength) due to increased fluoride content should be carefully monitored. As already mentioned in the Reception and Storage section, the refractory parts of SCL cannot be burned in a clinker kiln. Hence, unburned refractory particles will be remaining in the clinker. This is of less concern as cement grinding is not hampered. However, concerns might emerge if the clinker is sold to other grinding facilities, for visual inspection of the clinker by the customer could give rise to complaints.

Recommendations

- SCL affords an added value in the clinker production process. However, its use is limited owing to the high alkaline content. Positive effects are fluorine and alumina contents and the (low, but significant) calorific value.
- As SCL is a hazardous waste, and the aluminium industry has still been suffering from low recycling possibilities, a certain gate-fee as a service and handling-fee for SCL can be achieved.
- Adjust health and safety policy to the special features of SCL, e.g. gas generation on moisture exposure.
- Monitor thoroughly the clinker and cement quality with regard to setting and early strength development. Observe the alkali content in cement with regard to possible alkali silica reaction in concrete applications.
- Control visually the clinker with respect to colour and unburned refractory particles.
- Analyse accurately the fluorine content of clinker with regard to maximum SCL feeding rate in conjunction with observed cement properties.

HF emission control might become an issue, thus monitoring of stack emissions are to be enhanced.

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"Untapped Potential in "Informal Recycling" for Emerging Economies

By Ankur Saini, MVW Lechtenberg & Partner

Informal Sector

Introduction

Informal recycling sounds quite a fancy word if I want to put it in the right terminology it can be described as "Waste Picking" done by rag or waste pickers who salvage reusable and recyclables things discarded by others to sell or after personal use. The term "waste pickers" term itself is quite new adopted in 2008, the First World Conference of Waste Pickers in Bogotá, Colombia approved the word "waste pickers" to replace the derogatory term "scavenger." In many countries, cities, and contexts, many common names arise. Some of these names have been embraced by recyclers, while others have been dismissed as derogatory. The harsh truth changing the name to waste pickers for just the sake of it sounds better and on the other hand not providing their social status or officially acknowledging them doesn't make it better.

The mankind's producing an enormous amount of waste, which has major health and environmental effects. Domestic waste is rapidly accumulating in urban areas, and landfills are rapidly filling up in emerging economies or post-industrialised countries. Private companies and pricey technology, rather than waste pickers, are used in the global south. Waste pickers' access to recyclable materials is being limited as a result of the legislative move toward privatising waste management [1]. Even in society people are side-lining waste pickers, I come from one of the emerging country India and I have observed the people's mindset for waste pickers as a nuisance or source of shame for their communities. Even some will perceive them as a threat or will feel insecure in society when they are around the corner of the street and just trying to earn daily wages.

They seek recyclable things to sell to collectors or aggregators every day. The majority of their work is in landfills, where they are more likely to discover recyclables, but they must labour in challenging, frequently dangerous circumstances with little to no personal protective equipment (PPE). Mr. Dirk Lechtenberg can be seen in the picture below surveying one of the many landfills in India and behind him waste pickers collecting the recyclables without any protective gear and very poor hygienic conditions or none I would put in. Working conditions at the dumpsite can be harsh, and the risk to become ill or badly injured is a frequent occurrence for waste pickers. This not only threat to their health and lives, but it also means a day without food.

Figure 1: *Mr. Dirk Lechtenberg surveying a landfill in India and waste pickers behind collecting recyclables (Source: MVW).*

Waste pickers are frequently among the economically vulnerable members of society. Despite this, because the informal waste management sector operates on the fringes of the law, there are few laws in place to protect their job [2].

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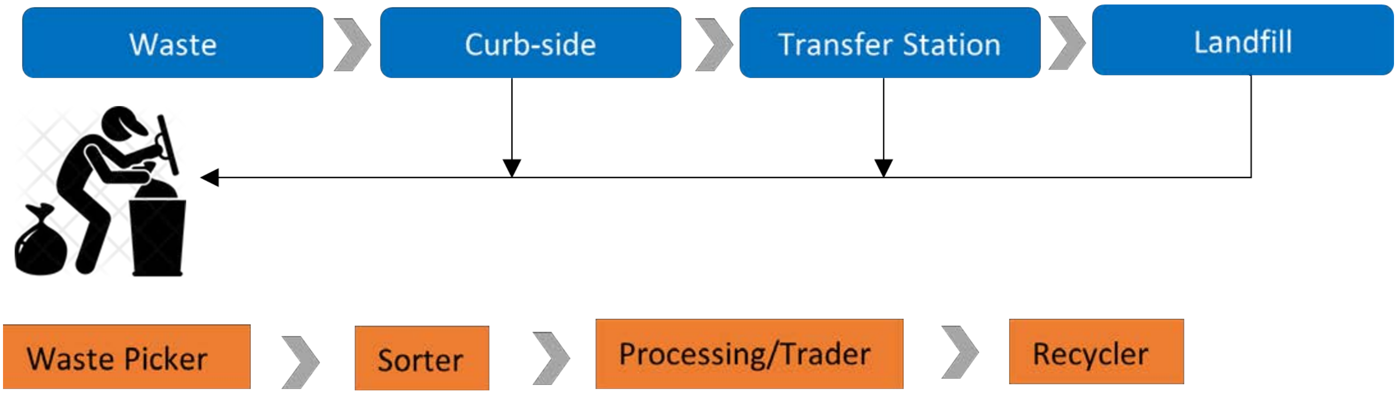

Figure 2*: Informal recycling supply chain in emerging countries (modified) [2].*

How Does the Informal Recycling System Work?

The informal sector has a highly robust and decentralized supply chain with significant volumes, particularly for plastic, paper, and metal, also other materials depending on the region, context and local market demand [3]. The private sector makes up the informal recycling sector. They are made up of individuals, micro, small or medium-sized businesses, and families or extended families that operate as businesses [4]. Figure 2 above shows the supply chain of informal recycling starting from waste pickers collecting the waste materials from households, roadside, waste collection stations and landfills. Waste pickers don't have their own shop/storage space to collect these recyclables and have to go to sorters or small-scale aggregators who own a small warehouse and do sorting on the periphery of the city.

These sorters/small-scale warehouse collectors will sell these recyclables to wholesale merchants or traders which will be further sold to recyclers that operate recycling and processing machines to process those recyclables into raw materials used in manufacturing activities for large-scale industries. According to statistics published in Women and Men in the Informal Economy: A Statistical Picture [5]; waste pickers account for less than 1% of the urban workforce in places where they have been identified:

- 0.1 - 0.4% in seven West African cities
- 0.7% in South Africa (this includes both formally employed and informal waste pickers)
- 0.1% in India

The statistics given above were most likely insufficient to capture all waste pickers.

Now, the question arises as to why to integrate the 'waste pickers' in growing city's solid waste management?

Well, the answers are already there in numerous reports on in formal recycling published by several prominent organisations like World Bank, World Economic Forum, GIZ and the list goes on….

Every report points out the importance of integrating informal recycling in terms of positive impacts on the socio-economic development of countries, environmental conditions and social status of waste pickers.

This article has further discussed this issue in terms of the importance of the integration of waste pickers and the gap between them and the waste management system of emerging economies.

Concept of Integrating 'Waste Pickers' in Recycling Economy for Global South

Policymakers at different levels from local government to large funding organisations like World Bank in Global South have tried to promote and implement the informal recycling integration in solid waste management (SWM) as part of a broader perspective towards a circular economy in the last decade. Yet researchers argue that integration adopted by a few countries was a total failure in terms of technical, policy and implementing points of view.

According to [6] collected work and research finding states on the informal economy and the new reforms on the informal workforce is not properly understood, underestimated, and generally stigmatized. The study also epitomizes the waste pickers integration in four different forms stated in table 1.

In Egypt, the law on waste management is being paved and especially on packaging for extended producer responsibilities German companies are advising them on the importance of integration of the informal waste pickers in the formal economy [7].

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Concept 1: Waste picker integration as a charity		
Integration focuses solely on the physical labour of collecting, sorting, cleaning, and selling materials on a daily basis	Rather than integrating their recycling system, programs focus on integrating waste pickers' labour	Waste pickers typically decline to be integrated into the ways that government and industry anticipate, resulting in project failure and negative consequences for the very salvagers that the programs promise to help
Concept 2: Waste picker integration as participation		
Integration of waste pickers as part of reclaimers' everyday labour to improve their livelihoods	Waste pickers are frequently assisted in forming and maintaining organizations to represent themselves in order to encourage meaningful engagement	Paying attention to the specific histories, politics, and other crucial features of different regions in order to determine the most appropriate ways to incorporate waste pickers' labour in a specific context
Concept 3: Waste picker integration as a multifaceted process		
The third concept emphasis on interventions in social, cultural, political, legal, and economic sectors, as each of these spheres, shapes waste pickers' job	Because reclaimers are stigmatized, a great emphasis is placed on social and cultural interventions to generate the recognition and respect for reclaimers that is essential for them to execute their work unobstructed	
Concept 4: Waste picker integration as social transformation		
Integration policies and programs for waste pickers are just as significant as the policies and programs themselves since they create new identities of citizenship	Reclaimers reshape their perception of the world and their place within it by organizing around integration	As a result, integration becomes one means of altering the prevailing oppressive and exclusive realities

Table 1: *Four different conceptualisations of waste pickers [6].*

Filling A Gap Between Informal Recycling and Existing Waste Governance

Waste pickers earn the lowest in the recycling chain and are frequently are subject to social stigma and economic exploitation, as they operate in unstable conditions in a competitive market. I argue that waste pickers are the top order of the recycling chain and should be rewarded as such. According to [8] waste pickers are the central piece for supporting the circular economy.

Waste pickers in several Latin American countries like Brazil and Argentina have formed cooperatives and groups during the last decade, forming regional networks and social movements [9]. Organized waste pickers have established a conversation with the government in order to be included in waste management programs, and have teamed with industry to provide waste collection and separation services under the extended producer responsibility (EPR) program. The daily job of waste pickers exposes them to a variety of waste, waste disposal, and resource recovery skills. The local government rarely uses these insights when establishing new waste management programs in their towns or installing recycling centers [8]. Local governments overall are unaware of the potential for more inclusive waste management to provide employment and income, particularly for youth and women, as well as to alleviate poverty [10]. Previous authors have given a pool of opinions for integrating the informal recycling sector within a city's integrated waste management system, as categorised in four complementary aspects outlined in figure 3:

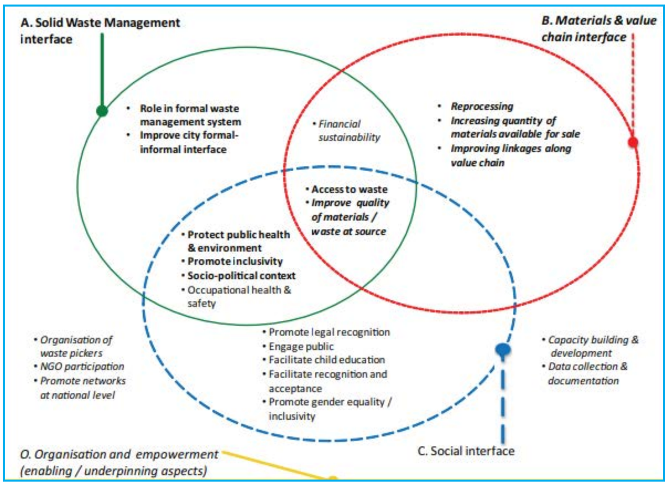

Figure 3: *Primary interfaces between the informal recyclers and the outside world [10].*

The four interventions between informal recycling and the outside world can be described as [10]:

A. The formal SWM system, which feeds materials for recycling to the informal sector;

B. The resources and value chain that sells those materials and thereby provides their principal source of income.

C. Society as a whole, encompassing many issues related to society's acceptance of their activities.

D. Informal recyclers' organisation and empowerment.

Figure 3 above depicts these interrelations in the form of a Venn diagram, which summarises the entire analytical framework and typology of interventions. The three interfaces (A) – (C) are depicted as three intersecting 'sets,' each supported by the informal recycling requisite organization and empowerment (O), which is critical to their performance. Each specific intervention from figure 3 are epitomised with examples in table 2:

(A) Interface with the SWM system
• ***Accessibility to the waste***: the legal right should be provided to recyclers, as well as the physical role in the system for primary collection. • ***Recognizing the importance of the informal sector:*** A solid waste platform, for example, should offer both service users and informal service providers a voice in how the system is planned and administered. • ***Environmental and public health protection:*** To minimize the health impacts to waste pickers and promote health benefits for them. • ***Strengthening interfaces:*** This comprises both physical interfaces, such as allowing waste pickers to easily deliver waste to the city's contractor for secondary transport to the disposal site or allowing recyclers at the transfer station or disposal site to have time and space to work and without disturbing the normal operating hours of the site.
(B) Interface with the materials and value chain
• ***Improving the quality of the source material:*** Promoting separation at the source so that wet (organic) and dry wastes are not mixed, and thus avoiding contamination of both organic products and recycled materials, not only increases the quality and value of the products but also addresses some of the fundamental ethical actual and perceived concerns about the waste pickers activities being 'dirty/unhygienic.' • ***Adding value to the products sold:*** In general, larger volumes of secondary raw materials command a greater price. The first set of interventions enhances the quantity available for sale, for example, by providing collectors with larger and/or mobile containers, or by providing room to store things prior to sale. A second group concentrates on reprocessing in order to add value to the product before selling it. Even low-cost and basic technologies, such as many phases of manual sorting or washing, can more than double the cost of the material. • ***Improving value chain connections:*** Improving communication can benefit the entire value chain. Forums to encourage communication and contract negotiations are examples of actions.
(C) Social aspects and the interface with society
• ***Facilitating informal sector recognition and acceptance:*** This includes legal recognition by the government, basically integrating what is referred to here as the "informal sector," as defined in the context of SWM, firmly within the formal economy. Facilitating registration is one of the most important interventions. • ***Work to improve child education, gender equality, and inclusion:*** Eliminating child labour necessitates improving people's incomes so that a family can afford to keep their children from working and allowing them to attend school. • ***Occupational H&S:*** Manual waste separation is a dangerous job. The hazards can be reduced by providing and encouraging the use of personal protective equipment , making health care more accessible, and ensuring that hazardous wastes are isolated from other wastes at the source.
(D) Organisation and empowerment
• ***Organising and structuring the informal recycling sector:*** Many have argued that self-organization is an essential first step in any intervention program in order to gain recognition as working partners from the city and to allow for collective bargaining with others in the value chain from a position of strength; indeed, many have argued that it is an essential first step in any intervention program. • ***Financial possibility***: The majority of informal recycling relies only on selling into the secondary materials market, where prices are frequently erratic. As a result, one set of initiatives focuses on lowering market volatility vulnerability. • ***Capacity building:*** One of the most important interventions is to increase capacity in the sector across a wide range of entrepreneurial and company management abilities, maybe supported by basic personal development thus increasing their education level.

Table 2: *Four interrelations of the informal sector and the outside world [10].*

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Informal Sector Boosting Local Waste Economy and Environmental Aspects

The informal sector primarily collects and recycles valuable materials. Only those materials with a high intrinsic value and on which they can earn a profit are extracted, processed, and sold by informal valorisation operations. All informal valorisation operations are profitable across the whole value chain. A study done on economies of the informal sector by [11] states that if the material is recovered by the informal sector through the door-to-door collection, it no longer has to be collected, therefore all costs - collection, transportation, and disposal – are lowered in proportion to the amount recovered. Also collected work done by GIZ [11] affirms that the amount of money saved on transportation is determined by where the material is recovered from the waste stream for recycling. Transport costs are not decreased if the material is recovered at the disposal location, but disposal costs are.

The informal sector generates environmental benefits for local authorities by participating in valorisation efforts, assisting them in meeting recycling targets and saving valuable and pricey landfill space. Recycling's environmental effects can be local - at the community or city level - or worldwide. While it is relatively easy to describe these consequences in qualitative terms, measuring them is more complicated, and putting an economic value on the many environmental impacts, both good and negative, is extremely difficult [11]. Recovery operations reduce carbon emissions by avoiding waste, reducing raw material extraction, and returning secondary raw materials to the production cycle, requiring less energy in recycling processes than primary raw material manufacturing processes [11]. These advantages are considerable, but they are very dependent on the recovery equipment employed and the material recovered, as different materials have different potentials for decreasing greenhouse gas (GHG) emissions.

At the end I would say the ability of informal sector to locate open niches in the waste and materials chain in the city is critical to their survival. Informal service providers, for example, identify and find potential for collecting in poor neighbourhoods. They locate and collect materials that are not already part of a materials cycle from disposal facilities and waste sources, and then complete the cycle.

In a nutshell, the waste pickers play a very important part in boosting economies and with that helping environment to be less polluted. Government or local urban bodies of the emerging economies should implement a mechanism that includes processes for integrating the informal economies and their organisations in the planning of waste management systems.

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Stationary fire protection with turbine

The EmiControls turbine technology makes it possible to throw water mist far and thus cool and extinguish very efficiently. In combination with infrared detection, fires can be fought and extinguished at an early stage.

Suitable for: larger storage areas (such as EBS warehouses), recycling plants, tank farms, chemical industry production plants, substations, and aircraft hangars.

www.emicontrols.com

Innovative Fire Protection: Mission - RDF which must not Burn

By Orglmeister Infrarot-Systeme

No matter which RDF (refuse derived fuels), secondary fuels or high calorific value fractions – all of these valuable materials have one thing in common: they carry a high fire load - a constant risk for those processing it in the recycling industry.

To start with the safe storage of the waste or raw material in input halls is an issue, and the risk increases during the individual processing steps such as crushing, sorting, magnetic separation, drying, etc. The secondary fuel should be used as such only once it has arrived at its incineration destination, but in no case before then.

The output area in storage halls is particularly at risk because this is where the prepared processing classes with high calorific value (RDF-MK, RDF-HK, FLUFF, etc.) are stored until they are delivered to cement plants, industrial customers or combined heat and power plants.

Figure 1: *This type of RDF warehouse carries a high fire load and should therefore be especially protected against fire outbreaks.*

Danger due to High Fire Load

High-calorific refuse-derived fuels are usually stored in bulk, in bales or in pellets and come with a lot of dust when loose. If the highly combustible material ignites, it quickly spreads to production and machinery, and endangers the manufacturing process or possibly the entire plant. To avoid injury, damage, and interruptions to production, it is vitally important to detect potential fire hazards at the earliest possible stage. The "time" factor is of outstanding importance in successful fire prevention.

Figure 2: *The loading or conveying process produces a substantial amount of dust and places high technical demands on fire detection.*

No Time to Lose in Fire Protection

For the earliest possible detection of fire hazards, infrared early fire detection with PYROsmart® has proven its efficiency in many RDF production facilities - over many years this technology has reliably prevented fires. PYROsmart® detects critical temperatures (so-called hotspots), which means it reacts much earlier than conventional fire detection systems.

Even under rough conditions, where other fire detection sensors fail or require high maintenance, PYROsmart® works very reliably and durably. Using a specially developed purge air system, the optics of the IR camera are kept free of dust and can therefore detect critical temperatures very accurately, even when exposed to large amounts of dust. This is monitored by regular self-test routines using an integrated test radiator and additional air flow senor.

Moreover, such "difficult" conditions such as dusty atmospheres impact only insignificantly on reliable temperature checks. The infrared radiation can permeate through polluted air, and even an image of the detection area is still visible (unlike video vision).

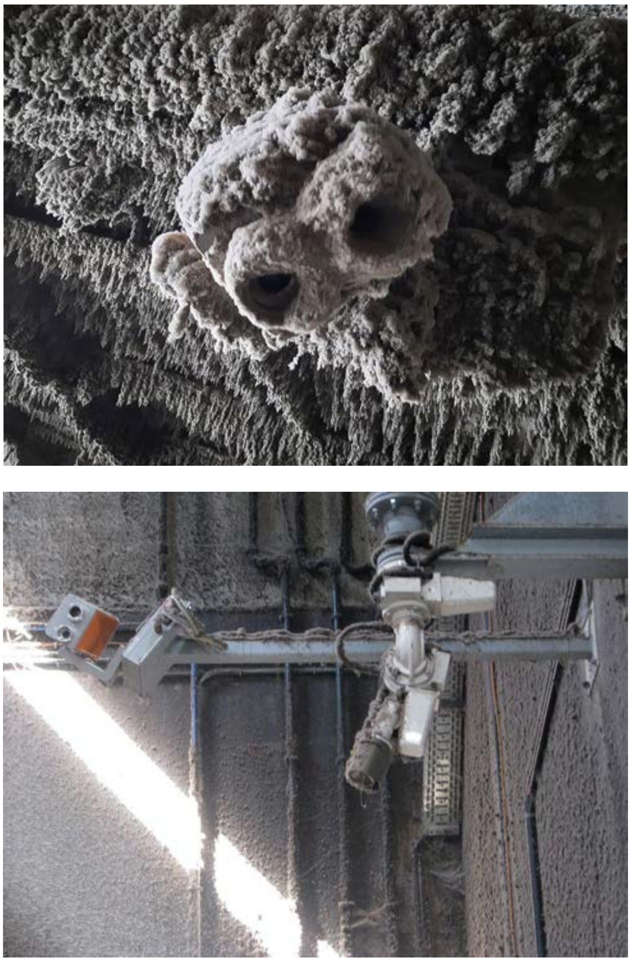

Figure 3*: The PYROsmart® device works reliably even under permanent dust exposure. The apertures of the optics for IR and video are permanently flushed with a compressed air jet, which keeps them clean and clear.*

Well-equipped against Deception Alarms

A special software algorithm, optimized over many years, differentiates between real fire hazards and everyday heat sources, such as those caused temporarily by vehicles, wheel loaders, etc. The result: safe and earliest possible hotspot or fire detection and hardly any false alarms. Operation runs smoothly and according to plan.

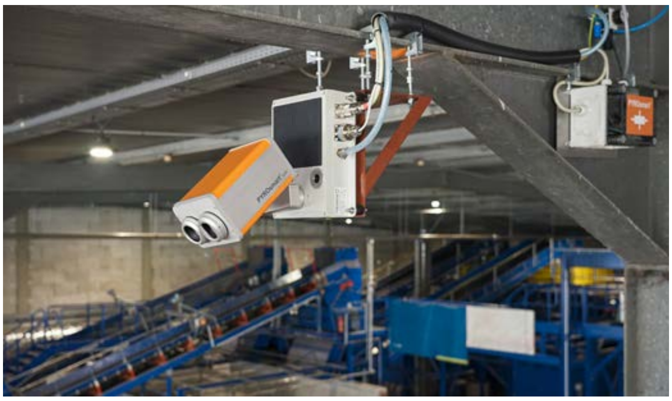

Figure 4*: VdS certified PYROsmart® FS pro monitors an RDF storage area.*

Early Extinguishing Ensures Fire Prevention

If PYROsmart® detects a critical alarm temperature in the RDF material, this is reported to the main fire alarm panel. By knowing the 3D room geometry, PYROsmart® can precisely locate the hotspot. The special PYROsmart® extinguishing software is compatible with all leading brands of extinguishing cannons. It controls the cannons fully automatically to cool down hotspots or extinguish incipient fires.

Targeted extinguishing is limited to the relevant hotspot area, does not affect any other areas, and so reduces downtime. If a fire spreads despite early detection (e. g. caused by explosive combustion), the PYROsmart® extinguishing software controls the targeted extinguishing process until the fire brigade arrives and takes over the required extinguishing measures. There is nothing more efficient or safer.

Figure 5*: Based on 3D spatial data, PYROsmart® can initiate targeted extinguishing attacks very effectively and economically.*

Proven Reliability

Orglmeister Infrared Systems have been able to prove the reliability and efficiency of the PYROsmart® system during many years of valuable practical experience. In 2015, the VdS, a testing institute of the German insurance industry for fire protection, published a guideline for the planning and installation of such systems.

The VdS guideline 3189 established rules for plant operators of how a plant with infrared technology in fire protection can be planned and implemented in practice. On this basis, the first certification for IR camera units in fire protection was issued in 2019. Orglmeister's innovative spirit and pioneering efforts in this very young branch of early fire detection set standards. The targeted and intelligent control of extinguishing cannons in a virtual detection room is a continuation of this innovation. Orglmeister's state-of-the-art

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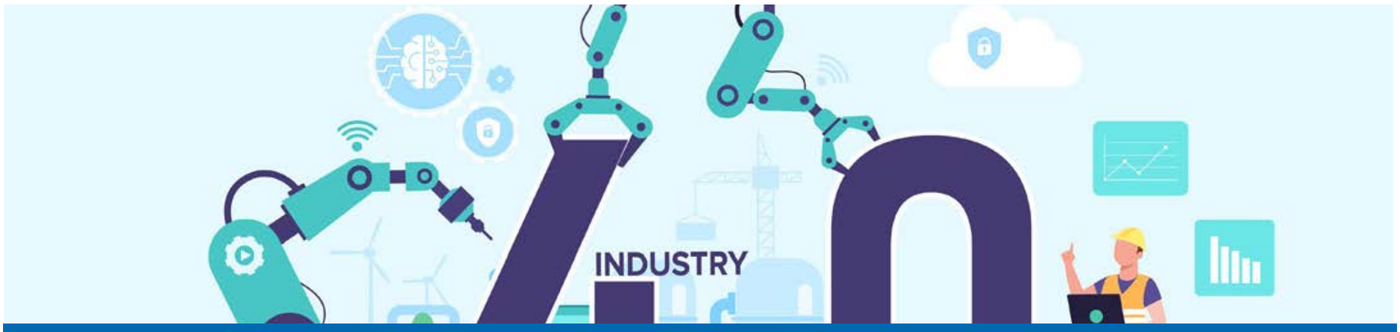
approach is again ahead of the official certification bodies.

Many customers from industries with high fire risk recognize the advantages of this technology and implement respective concepts to achieve higher safety standard (even deviating from established regulations). Many customers now confirm this approach is paying off. Various large insurance companies approve of this innovative fire prevention concept and classify companies using this technology into a lower risk category. An advantage to be considered when it comes to agreeing insurance cover and selecting the right partner.

The advantages at a glance:

» Quick and easy overview of all monitored areas, video and infrared panorama.
» Early detection of potential fire hazards
» Reliable operation even in permanently dusty environments
» Exact localization of dangerous hotspots
» Fully automatic control of targeted cooling or extinguishing
» Minimal use of extinguishing agents or low clean-up costs
» Minimization of operational and production interruptions
» Manual takeover of the extinguishing system by the fire department is possible at any time
» Clear operation and possibility of early intervention by organizational fire protection already at pre-alarm stage
» Full thermal documentation



INDUSTRY 4.0: A Way Ahead

By Ankur Saini, MVW Lechtenberg & Partner

It's clear from the title name that in waste treating facilities, collection centres and even in landfills, the rise of robots and unmanned autonomous vehicles is going to be our labour. It makes sense also consider how many labourers work in these collection points or waste sorting facilities endangering their health. Intelligent robots will step into human shoes to do all the hard labour of mankind and that era is already ongoing the technological advancement is happening in waste management sector not only in robotic recycling arms but also in big data for services users and the Internet of Things (IoT) applications.

According to [1] there is stated that "We are in the beginning stages of the fourth industrial revolution, as many people refer to it". Digitization has already impacted a wide range of sectors. Global digital networks, innovative materials, massive data streams, rising computing power, and alternative energy sources all lead to the growth of an entirely new generation of possibilities, processes, and solutions [1].

The challenge of this era is not only to increase the economy but also to reduce resource use and environmental deterioration. The underlying causes of the current global crisis must be addressed.

Industry 4.0 and the circular economy are massive issues with monetary values in the trillions of dollars. One

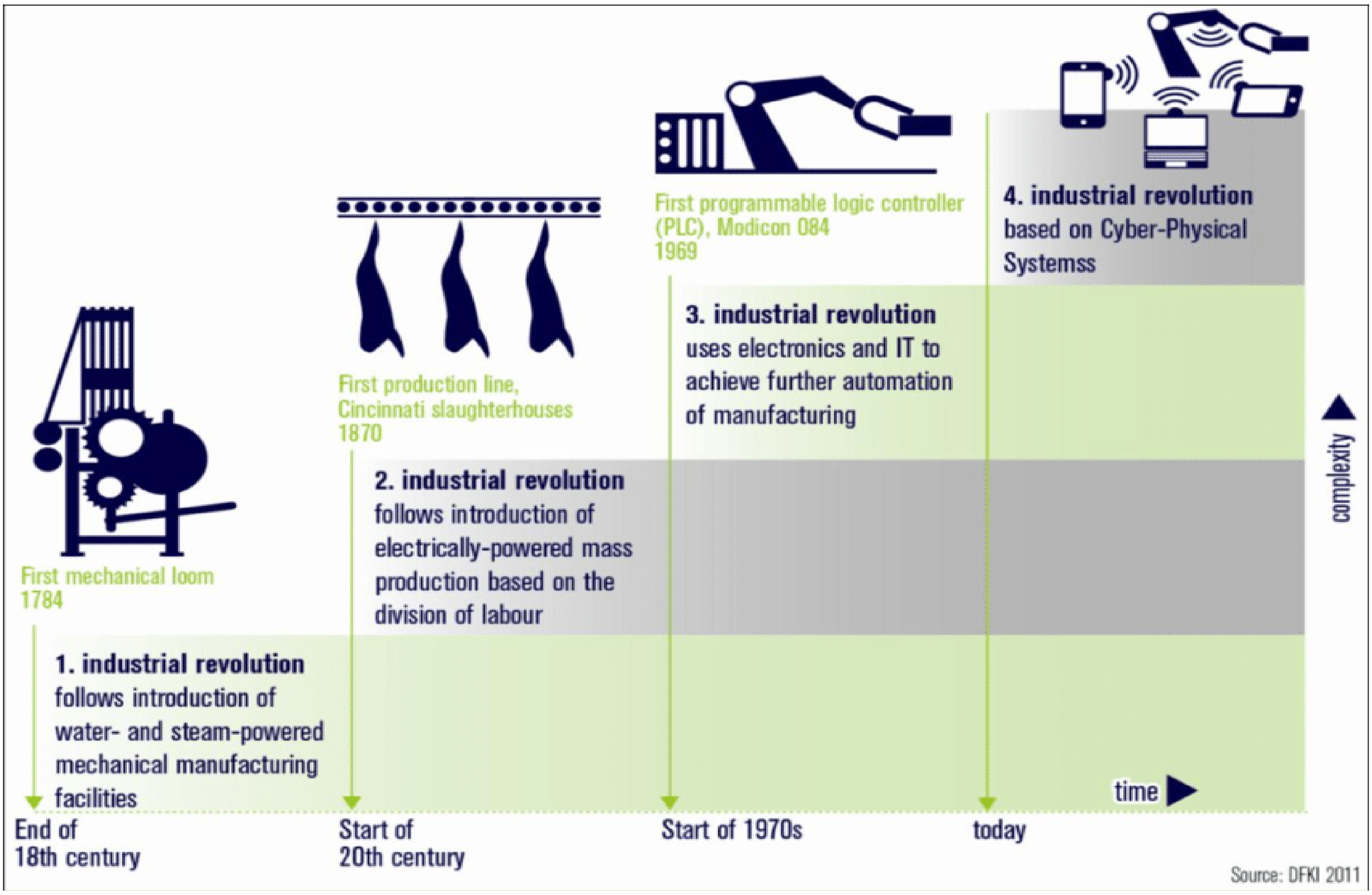


Figure 1: *The four stages of the industrial revolution [2].*

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of the most important factors to consider is that a transition to a circular economy, which requires a major reorganization of economic inputs and outputs in all industrial supply chains, may be the only way to sustain long-term economic development [1]. Revolutions are notorious for being a turbulent experience. Scientific advances abound, with potentially unexpected results. Digital platforms have surpassed the industrial firms of the previous era as the world's largest and most lucrative businesses as shown in figure 1. The degree of complexity rose with each industrial revolution.

A New Tool to Contribute to the Circular Economy

Industry 4.0-enabled solutions now have been regarded as critical to the circular economy's success by researchers. The Ellen MacArthur Foundation has defined a circular economy as a global economic model to curtail stress on the finite sources of raw materials humankind has on this blue sphere [2]. The researchers also argue that a company willing to become circular cannot side-line considering Industry 4.0 within its value chain.

Figure 2 encompasses the technological advancements or scientific breakthrough caused by Industry 4.0 and directly or indirectly how its contributing to circular economy. Industry 4.0 is a concept that integrates information and communication technologies (ICTs) with manufacturing and production process [3].

The question is how Industry 4.0 solution is impacting a real-world supply chain in the circular economy? The circular economy principle is to transform the traditional business model's linear production pattern (receive, make, use, and discard) to a circular system in which resources circulate up- and downstream in the supply chain. Industry 4.0 can play an important role in innovative logistics and supply chain ecosystems which will directly enhance this movement [4].

As illustrated in figure 3, Industry 4.0 applications can be divided into direct and indirect impacts for the circular economy. Direct effects are those that result from improvements in resource or energy efficiency as a result of leaner methods of production and improvement in efficiency, as well as a reduction in excess waste or production [5]. Indirect impacts are benefits provided by Industry 4.0 technologies that are not directly related to the manufacturing process. They may include, for example, resource and energy efficiency improvements, as well as assessment and monitoring along the value chain [6].

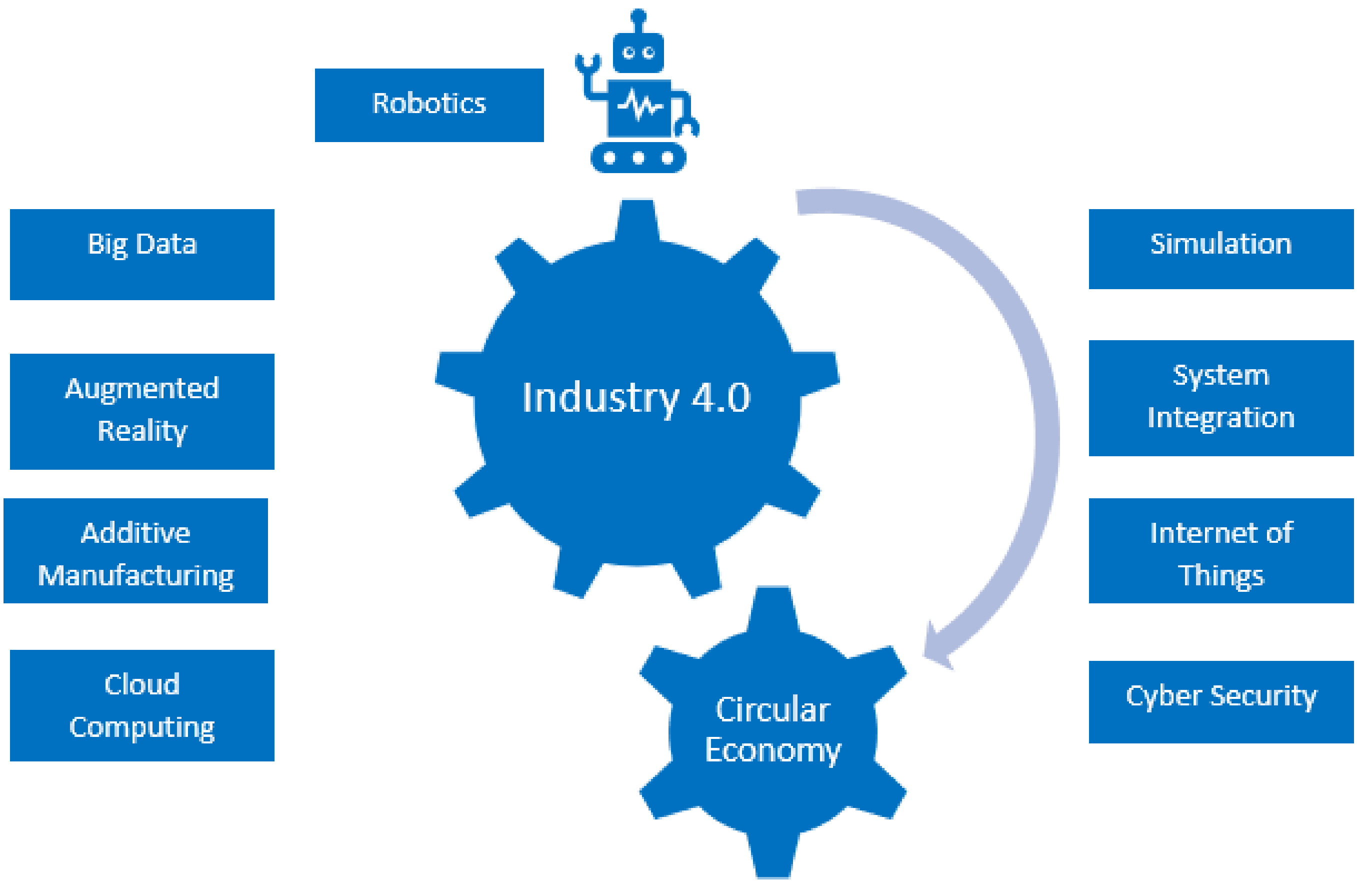

Figure 2: *Technological integration in Industry 4.0 and contributing to circular economy (modified) [3].*

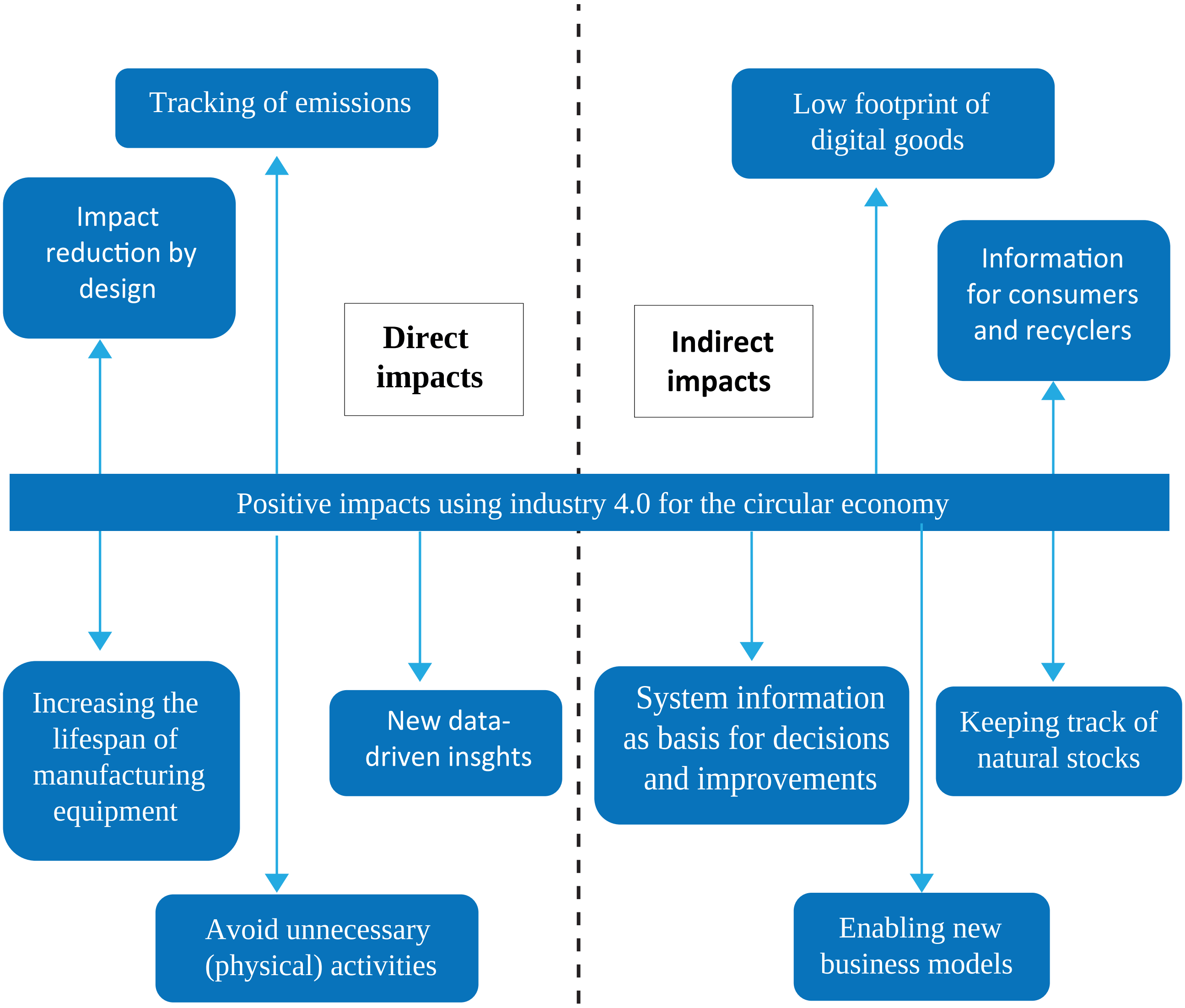

***Figure 3**: Impacts of Industry 4.0 [6].*

In contrast to a linear economy, a circular economy is more reliant on data and information. Digital technologies can help unlock the potential of specific circular methods by providing the essential information, which has been observed in the report published by OECD on improving recycling markets in 2006 [7]. High-value recycling of metals and plastics, for example, involves not just detailed information on material composition parameters, but also market-related information such as availability and supply, which is critical for lowering the cost of production [8]. The same can be said about other industrial processes. Redesign, for example, demands a thorough understanding of user behaviour in order to facilitate logistics, design, and distribution. Virtual services, such as simulations, can enable some instances of rejection rather than material offers, but they must be digitalised in order to gain this knowledge about the associated processes [6].

According to a UN Environment Programme International Resource Panel Report published on metal recycling, pointing out the constraints of a material-centric approach that worked for base metals in the past but is increasingly failing for complex products, production processes, and value chains [9]. The report states that due to current advancement in technology of 21st century products have become more complicated, incorporating practically any metal or other element. Recycling these products became more complex as attempting to recover one item often resulted in the destruction or scattering of another, and it became evident that a product-centric approach was required [9]. From my point of view energy intensive industries integration with Industry 4.0 can provide this product-centric approach with enabling new industrial and cost-cutting methods, with lesser emissions and avoiding the health hazards for human beings.

Recycling System in Hands of Autonomous Robots.

Waste management has already been changed by the digital revolution, particularly in the last decade. 'Cyber-Physical' systems like smart trucks equipped with GPS (Global Positioning System), robotic sorting plants, RFID (Radio-frequency Identification) Bin Tags and Scanners, smart containers equipped with sensors are already integrated into the waste management systems [1].

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According to [10], the worldwide robotic waste-sorting system market would climb up at a compound annual growth rate of over 20% by 2026. North America is taking a lead for incorporating robots in waste-sorting plants [10]. Various robotics manufacturers are getting breaking through into the waste management industry. Fanuc, one of the world's largest robot manufacturers collaborated with the Artificial Intelligence (AI) vision system of Recycleye to automize the recycling industry [11]. According to Recycling Magazine, the robotic sorting system has already been installed in two resource recovery facilities in the UK, several plastic and paper sorting lines, even in France [11]. AI-powered robotic waste sorters will set new ground rules for the waste sorting plants in the future.

This Isn't a Novel Concept for Cement Kilns

AI is not a new idea in cement industries as various components of AI are used far back in the 2000s. Depending on the tasks, different AI modules are applicable like Fuzzy logic for closed-loop control, Neural Nets search for hidden patterns in the process and MPC used for the well-understood process [12]. The cement industry is not lagging towards integration of 'Industry 4.0' solutions, a recent breakthrough in cement plants for adopting KIMA 'MILLMASTER' system, originally designed for the selected cement plants of the Holcim group as well as in KIMA process control back in 2008 [13]. The new designs were developed later for human-machine interface, programming logic, and new software modules to be fully automated. At the plant in Dunkerque, EQIOM Ciments fully autonomous mill is in operation by AI using 'MILLMASTER' mainly producing slag cement. Some other successful examples for running 'MILLMASTER' are Fabrika Cementa Lukavac in Bosnia and Optera Karsdorf in Germany. The capabilities of AI are still limited and its components used now are identical to those adopted 10 or 20 years ago. However, computers have gotten considerably faster and have access to large amounts of past data. Now the question is what are the biggest impacts of Industry 4.0 in the cement sector in terms of challenges/benefits?

To answer this question, I would put another question why do we even need Industry 4.0 in the cement industry? The answer goes without saying every cement producer around the world wants to optimise production and in order to achieve that Industry 4.0 can play an important role. Boston Group Consulting has pointed in their report there are five particular areas of Industry 4.0, where the cement sector has great potential to gain benefits [14].

» Analytics-Driven Predictive Maintenance
» End-to-End Optimisation via Digital Twin
» Predictive Quality Analysis
» Alternative Fuel Optimisation
» Integrated Control Towers

In order to gain these benefits, there are quite a lot of hurdles to cross first, according to [14] the first challenge is to strategize the definition of Industry 4.0 and then rethink of organisation and process to maximise the outcomes by conducting successful pilot studies. On top of management point of view, there are some practical, technological and ecosystem-related complications with regard to the integration of Information Technology (IT) and Operation Technology (OT) [15]. There are also concerns about data compliance and in uncertain times, risk management and cost reduction are essential. Managing the integrated supply chain's complexity, improved understanding of IT and OT technologies and more essential, how to use them [15].

Certainly, with challenges, there are always substantial risks regarding data management and cyber security. As IT and OT merge, there will be a rise in the number of cyberattacks in the Industrial Internet of Things. Furthermore, security issues are one of the primary factors holding back IoT activities, even though IoT is a fundamental component of Industry 4.0 [15].

The digital transformation is going to pave the road for every industrial sector either it's a waste management industries or cement sector from smart manufacturing to digitise the entire value delivery channels. But in order to deliver the smart or improved productivity, it's important for every industry to setup a clear long term vision for growth and leadership teams driving behavioural change, digital transformation will certainly excel [16].

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Company News

MVW Lechtenberg Opens Branch in Saudi Arabia!

Dirk Lechtenberg's first visit to Saudi Arabia was about 20 years ago. He described it as follows; “The desert was so huge, wherever you lay the eyes there is just calmness and heat”.

A cement manufacturer invited MVW to investigate whether their plant is capable to operate on alternative fuels through tires and municipal solid waste (MSW) or RDF. The visit was quite extraordinary in terms of knowing their cultures, meeting friendly people and the industries. However, with a fuel price of almost nothing around 20 US$ per tonne (not barrel of heavy fuel oil) the odds to implement alternative fuels at that time can be said to be long overdue.

Times have changed and the government and industries have now realised about climate change and are investing more into alternative fuels. In 2010 MVW supported the Ministry of Environment in a “Mandatory Energy Efficiency Program” to support the industry in energy savings measures.

Almost 4 years ago, another cement manufacturer contracted MVW to implement alternative fuels in their cement plant. MVW emphasized to the plant’s management, that whatever we do in Alternative fuel development, will not be economic. However, the former CEO of the company explained to us as follows: “you know, we are Arabs, when we travel with our camels in the desert, we know that we can travel for 3 weeks without water. In these three weeks, we’ll continue on a straight path. We’ve made the decision to switch into alternative fuels, as they are environmentally friendly and will be the future for our industry. We now decided to move in this direction and as long as we have water we will move straight forward”.

By end of 2020, MVW installed the first RDF production facility in Saudi Arabia, implemented the use of shredded tires, and the cement plant now is operating continuously using alternative fuels. Besides this, we have been advising the Ministry of Energy and are looking forward to supporting the Vision 2030 by his Highness, Crown Prince Mohammed bin Salman al-Saud. The new office in Riyadh is a joint venture with one of the leading local investment funds.

Mr. Lechtenberg is pictured with a camel while having a rest in the desert of Saudi Arabia.

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We are Hiring!

Project Manager (m/f/d)

We are MVW Lechtenberg & Partner, the global leader in the processing and use of waste derived fuels in the cement and lime industry headquartered in the port of Duisburg, Germany and currently looking for a new colleague to support our project team.

You should be willing to gather business experience combined with positive environmental impacts. Like all members of our company, you should be able and curious to cover various topics or be willing to learn something new. We value our flat hierarchies and flexibility.

Your Responsibilities

- In brief, you will support the project team leader.
- You will research (technical, economical, legal), prepare decision bases, create presentations and pitches, take over communication channels and more. Daily tasks are therefore quite variable.
- Close cooperation with the project team regarding technical requests, proposal and contract rechecks.
- Accompany internal quality procedures, key account management and more.
- You will be the coordinator between the manager and our interdisciplinary teams (regarding work packages and ensuring compliance with milestones, costs and quality, new clients etc.).
- You will support our team leader regarding team monitoring, staff development and capacity planning measures.
- Formalization, visualization and communication of the company vision, strategies, product/service pitches and process development approaches.
- Active tracking of project execution and business development approaches.

Your Profile

- Knowledge of and strong interest in environmental and recycling matters (technologies, trends etc.).
- You should be mindful, proactive, and anticipative in your activities.
- Educational background in waste management, industrial engineering or other (technical) engineering background (minimum MSc. degree) with at least 2 years of relevant working experience.
- An outgoing, friendly, and assertive personality.
- Strong organizational skills and attention to details. Strong written and verbal communication skills in German (minimum B2 level), English fluently, other language skills are a plus.

Our Offer

- The great chance to be part of a growing, globally active, young company (without startup attitudes).
- You will be in tight communication with our company's leadership. Learn and support how to bootstrap an international company group, which is focused on positive social and environmental impact.
- Get to know our diverse network, customers, and partners from all over the world. You will meet a wide variety of people and topics on time.
- Diversified activities with insights into many areas of environmental protection, waste treatment, carbon reduction, etc.
- The demand, space, and support to bring in your ideas and their realization.
- A high level of responsibility and development opportunities from day one onwards.
- Our office with view to the river Rhine and Ruhr in Duisburg- Ruhrort, short ways and direct communication with the team, as well as the management.
- Great colleagues from all over the world!

Do you want to be part of our team?

You are invited to become a member of our (pleasant) team in a fast and coordinated growing company. With the right amount of commitment, flexibility and enthusiasm your destiny will be in your own hands to ascend the corporate ladder.

We look forward to receiving your CV and your unique way of presenting yourself (you choose the digital mean) as soon as possible at office@lechtenberg-partner.de . Be creative and present yourself!

NEWS MVW

Global News

- COP26 First Movers Coalition Members include Cemex, Dalmia Cement and Holcim

America

United States

- U.s - Lafargeholcim Reveals New Info on the Carbon Capture Research at the Ste. Genevieve Cement Mill Has Been Released by the United States

Canada

- St Mary's Cement Intends to Use Alternative Fuels at its Cement Facility

Honduras

- Argos will Collect 5000 Discarded Tyres Every Month in Honduras

Asia

India

- Ultratech and Jk Cement Have Gigned an MOU with Prespl for Agro Waste Fuel

Indonesia

- Flsmidth Won the Contract for Delivering AF System in Indocement
- The Indonesia Government Intends to Impose a Carbon Tax to put a Price on Emission

Philippines

- Cemex Philippines is Planning to Invest in Green Cements and Co-Processing

Europe

Germany

- Mainz University Chemists find a Method For Manufacturing Cement by Milling Rather than Burning Lime

France

- Vicat will Invest Eur 800 Million to Meet the 2030 Climate Goals

Bosnia

- Lukavac Alternative Fuel Initiative

United Kingdom

- Ribblesdale Cement Plant is Hosting the First Commercial Net-Zero Fuel Trial in the UK
- Ineos is Seeking For Bids For a World-Scale, Low-Carbon Hydeogen Facility at Grangemouth
- Cemex UK Invest 25 million US $ to Phase Out Fossil Fuels at Rugby Cement Plant

Middle East

Iran

- Iran‘s Cement Industry is Exploring Alternatives in the Midst of a Fuel Crisis

Iraq

- RDF Usage Initiative by Gasin Cement

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Global News

COP26 First Movers Coalition Members Include Cemex, Dalmia Cement, And Holcim

Cemex, Dalmia Cement, and Holcim are among the founding members of COP26's First Movers Coalition public-private partnership. The alliance intends to leverage its worldwide purchasing power to develop markets for emerging CO_2 emission reduction technology in order to expedite and scale collective effect toward global emission reduction goals. The coalition estimates that currently available technologies will reduce CO_2 emissions by 82 % by 2030 and 50 % by 2050, while future technologies would reduce CO_2 emissions by 15 % by 2030 and 46 % by 2050.

Source: Global Cement: "Cemex, Dalmia Cement and Holcim among founders of COP26 First Movers Coalition." Published on 05 May 2021, https://www.globalcement.com/news/item/13237-cemex-dalmia-cement-and-holcim-among-founders-of-cop26-first-movers-coalition.

America

U.S - Lafargeholcim Reveals New Info on the Carbon Capture Research at the Ste. Genevieve Cement Mill Has Been Released by the United States

The project's goal is to complete a front-end engineering design (FEED) study for a carbon capture retrofit that can separate up to 95 % of the plant's CO_2 emissions. The captured CO_2 will be 'pipeline ready' for geological storage, and the research will also include a socio-economic impact analysis. In early October 2021, the US Department of Energy's National Energy Technology Laboratory awarded the Prairie Research Institute at the University of Illinois US$4 million to work on the project. Lafargeholcim will use Air Liquide's Crycocap FG system.

Source: Business Insider: "LafargeHolcim US reveals more detail on carbon capture study at Ste. Genevieve cement plant." Published on 03 November 2021, https://markets.businessinsider.com/news/stocks/lafargeholcim-us-reveals-more-detail-on-carbon-capture-study-at-ste--genevieve-cement-plant-10700915.

Canada- St Mary's Cement Intends to Use Alternative Fuels at Its Cement Facility

St Mary's Cement is to file for a license to replace a proportion of its coal, gas, and petcoke fuel mix with alternative fuel (AF). In May 2011, the facility conducted a two-week AF replacement study. According to CBC News, Votorantim Cimentos' subsidiary will propose its idea to the broader public at an evening gathering on November 18, 2021. According to the organization, similar AF agreements will be implemented at its Bowmanville plant, which utilizes 90,000t/yr of biomass, construction and demolition wood, and non-recyclable paper and plastics.

Source: Global Cement: "St Mary's Cement plans alternative fuels use at St Mary's cement plant." Published on 18 November 2021, https://www.globalcement.com/news/item/13298-st-mary-s-cement-plans-alternative-fuels-use-at-st-mary-s-cement-plant.

Honduras - Argos will Collect 5000 Discarded Tyres Every Month in Honduras

Argos, a Colombian company, will collect approximately 5000 discarded tyres per month in Choluteca, Honduras, and transport them to Comayagua for disposal at its Piedras Azules cement facility.

Cementos Argos is collaborating with Fundesur and Fundación HERCO to effectively launch the Responsible Waste Tyre Management program in Choluteca. The three organizations hope to remove around 60,000 tyres in the first year of the scheme, which has the backing of MiAmbiente, the Secretary of Health, and the Municipal Mayor of the town. Argos has co-processed more than 1 million tyres in its cement kiln in the past few years.

Source: International Cement Review: "Argos to collect 5000 waste tyres per month in Honduras." Published on 24 November 2021, https://www.cemnet.com/News/story/171801/argos-to-collect-5000-waste-tyres-per-month-in-honduras.html.

Asia

India - Ultratech and JK Cement Have Signed an MOU with PRESPL for Agro Waste Fuel

UltraTech Cement has announced that it has signed a non-binding memorandum of understanding (MoU) with Punjab Renewable Energy Systems Pvt Ltd. (PRESPL). The MoU is part of UltraTech's efforts to decarbonize its operations, and it aims to considerably increase the use of biomass to substitute fossil fuels like coal in UltraTech's manufacturing processes. PRESPL will use its technological competence to replace coal-based systems with biomass-based processes un-

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der the terms of the agreement. The biomass-based initiatives will be implemented by PRESPL at three UltraTech plants. These three initiatives are expected to save about 150,000 tonnes of CO_2 per year when integrated. Whereas JK cement planned to increase the usage of AF in their kilns and this 10-year MoU with PRESPL, JK Cement's efforts to decarbonise its operations, with the company aiming to dramatically increase the usage of biomass and other alternative fuels.

Source: International Cement Review: "UltraTech and PRESPL sign MoU for agri waste fuel." Published on 14 October 2021, https://www.cemnet.com/News/story/171560/ultratech-and-prespl-sign-mou-for-agri-waste-fuel.html.

International Cement Review: "JK Cement looks to scale up biomass use with new MoU." Published on 25 October 2021, https://www.cemnet.com/News/story/171619/jk-cement-looks-to-scale-up-biomass-use-with-new-mou.html.

Indonesia - Flsmidth Won the Contract for Delivering AF System in Indocement

PT Indonesia Tunggal Prakarsa Tbk, a HeidelbergCement subsidiary, will replace the majority of its coal use with a full alternative fuels solution from FLSmidth, which will offer a MissionZero flagship product. The Indonesian cement manufacturer will be able to use municipal waste and biofuels as a result of the project. Indocement is one of Indonesia's leading cement producers with a total capacity of 25 million tpa.

FLSmidth will deliver the new HOTDISC-S to the Indocement plant on the outskirts of Jakarta, which can convert a wide range of alternative fuels, including municipal waste and biofuels, into a consistent heat source for its SLC Calciner.

Source: FLSmidth Press Release: "FLSmidth powers INDOCEMENT'S move from coal to alternative fuels in Indonesia." Published on 25 November 2021, https://www.flsmidth.com/en-gb/company/news/company-announcements/2021/flsmidth-powers-indocement-s-move-from-coal-to-alternative-fuels-in-indonesia.

Indonesia - The Indonesian Government Intends to Impose a Carbon Tax to Put a Price on Emissions

The Government of Indonesia (GOI) passed Law Number 7 in the Year 2021 on the Harmonization of Tax Regulations on October 7, 2021. (UU HPP). Several existing tax rules were changed, and a new carbon tax was imposed. This is the first time Indonesia has imposed a carbon tax, even though 26 other countries have already done similarly.

The carbon tax is based on a cap and tax scheme, which puts a price on carbon emissions that exceed a certain limit. Beginning in April 2022, the GOI plans to test the tax in the coal-fired power generation industry. In order to achieve its ambitious goal of reducing CO_2 emissions, the government of India intends to build a carbon trading market system as well as expand the carbon tax to other industries other than coal-fired power generation by 2025.

Source: DevTech Systems, Inc.: "On Indonesia's new carbon tax and its effectiveness at reducing greenhouse gas emissions." Published on 24 November 2021, https://devtechsys.com/insights/2021/11/24/on-indonesias-new-carbon-tax-and-its-effectiveness-at-reducing-greenhouse-gas-emissions/.

Philippines - Cemex Philippines Is Planning to Invest in Green Cements and Co-Processing

At the present, green cement accounts for 80% of Cemex Philippines' cement output. It intends to manufacture 100 new-generation cement products shortly. As a result, Cemex's Apo Cement facility in Cebu is aiming for new-generation cement or green cement products, along to get energy from renewable sources, such as utilising waste materials like plastic, paper, cardboard, and fabric to fuel its power requirements.

Investment has been made to increase the thermal substitution rate from imported coal to solid recovered fuels. Currently, at Apo facility, 50,000 tpa of RDF is co-processed, which they intend to increase the co-processing up to 400,000 tpa of waste. Cemex Philippines' Apo Cement and Solid Cement plants currently have a combined capacity of 5.7Mta.

Source: Ehda M. - The Freeman: "Cemex targets to take lead in green cement production." Published on 22 November 2021, https://www.philstar.com/the-freeman/cebu-business/2021/11/22/2143024/cemex-targets-take-lead-green-cement-production.

Europe

Germany- Mainz University Chemists find a Method for Manufacturing Cement by Milling Rather than Burning Lime

Chemists from Germany's Johannes Gutenberg University Mainz (JGU) have developed a technology that, in the long run, might dramatically reduce CO_2 emissions from cement production. In this method, raw limestone ($CaCO_3$) is milled with solid sodium silicate (Na_2SiO_3) rather than being turned into burnt lime in coal-fired kilns. This milling phase produces an "activated" intermediate containing the cement constituents in a homogeneous distribution. When treated with sodium hydroxide solution, a product with a structure similar to calcium silicate hydrates is generated. The creation of cement paste and water setting occurs via a complicated chemical cascade.

Mainz-based chemists emphasize the cost and process are rough estimations and lab-scale tests cannot be compared with industrial-scale projects, where parameters such as development, design, feasibility, maintenance and various other factors have to be considered.

Source: Johannes Gutenberg University Mainz: "Long-term carbon dioxide emissions from cement production can be drastically reduced." Published on 09 November 2021, https://www.uni-mainz.de/presse/aktuell/14466_ENG_HTML.php.

France - Vicat Will Invest EUR 800 Million to Meet the 2030 Climate Goals

The French manufacturer has been outlining how it would meet its 2030 and 2050 emission objectives throughout the building materials value chain. Vicat estimates that only to reach its 2030 targets, it will need to invest about EUR800 million. Vicat has set a 2030 emission goal for the group of 540kg CO_2/net tonne of cement produced, a reduction of 13% from 2019.

Vicat's roadmaps and project aim to reduce CO_2 emissions by 430 kg every net tonne of cement manufactured in Europe by 2030, with the company aiming for carbon neutrality by 2050. Vicat's CO_2 reduction action levers will include replacing fossil fuels by alternative fuels and expanding waste treatment businesses. By utilizing locally available materials such as calcined clays, limestone, or pozzolans, the clinker factor will be lowered.

Source: International Cement Review: "Vicat to invest EUR800m to meet 2030 climate targets." Published on 19 November 2021, https://www.businesswire.com/news/home/20211116005949/en/Meeting-on-Vicat%E2%80%99s-Climate-Strategy.

Bosnia - Lukavac's Alternative Fuel Initiatives

The Lukavac cement plant in Bosnia has been using the dry-process method with a kiln line designed by KHD Humboldt Wedag. In 2009, the single-string five-stage preheater with calciner has been erected. The plant has been increasing steadily the input of heat from AFs to achieve 30%, although the increase of AF usage of 30% was limited due to the low retention time of AFs and the mass load in the calciner. To increase the usage of AF from 30% to 50% the reconstruction of the precalciner was necessary. To incorporate solid alternative fuel in the excess of 90% in the calciner, a design study has been carried out, and the KHD Pyroclon calciner was modified with a separate pyro-string and a low-NOx string, and turned to a state-of-the-art inline calciner. For feeding AF to the main burner Lukavac launched new projects investment in 2019, for a fully-automated RDF handling equipment with storage, dosing and mixing option.

***Figure 1**: At the Lukavac plant, a five-stage cyclone preheater from KHD Humboldt Wedag and A TEC Production & Service calciner and bypass system were installed.*

Source: International Cement Review: "Lukavac's AF initiatives." Published on 14 September 2021, https://www.cemnet.com/Articles/story/171407/lukavac-s-af-initiatives.html.

United Kingdom - Ribblesdale Cement Plant Is Hosting the First Commercial Net-Zero Fuel Trial in the UK

The project, funded by the Mineral Products Association (MPA), Hanson UK, and led by the Department of Business, Energy, and Industrial Strategy (BEIS), employed a mix of 100% net zero fuels for the first time in commercial-scale cement production. The fuel mix included tanker-delivered hydrogen, meat and bone meal (MBM), and glycerine, indicating the path to eliminating the use of fossil fuels in cement and concrete production. The ratio of fuels in the cement kiln's main burner was gradually increased to a total net zero mix of grey hydrogen during the demonstration at Hanson Cement's Ribblesdale plant in Lancashire. In the future, this will be replaced by green hydrogen.

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If completely implemented for the entire kiln system, almost 180,000t of CO_2 may be saved each year at Ribblesdale alone as compared to the site's traditional fuel of coal.

Source: Hanson Heidelberg Cement Group: "World first net zero fuel trial success at Ribblesdale". . Published on 29 September 2021, https://www.hanson.co.uk/en/news-and-events/world-first-net-zero-fuel-trial-success-at-ribblesdale.

United Kingdom - Ineos is seeking for bids for a 'world-scale, low-carbon hydrogen facility' at Grangemouth

On the 27th of January 2022, chemical giant Ineos has announced that it is seeking engineering and design firms to bid on the next stage of its plans to generate low-carbon hydrogen at its Grangemouth facility in the United Kingdom. Ineos has long planned to invest £1 billion in blue hydrogen generation and consumption at its Grangemouth, near Falkirk.

The company had earlier vowed to reduce emissions at the facility by 60% by 2030, before reaching net-zero by 2045, and had allocated £500 million to do so.

***Figure 2**: Ineos power plant facility at the Grangemouth,*

Source: Edie Newsroom: "Ineos seeks tenders for 'world-scale, low-carbon hydrogen plant' at Grangemouth." Published on 27 January 2022, https://www.edie.net/news/8/Ineos-to-construct--world-scale--low-carbon-hydrogen-plant--at-Grangemouth/.

United Kingdom - Cemex UK: Invests 25 million US$ to Phase-Out Fossil Fuels at Rugby Cement Plant

Cemex UK has invested US$ 25 million since the first quarter of 2021 into a new system to further replace fossil fuels at its Rugby Cement plant. After the successful trial of the investment included the usage of green hydrogen for the production process at Cemex's Alicante cement plant in Spain. The new technology used for the production process shows the potential to cut huge CO_2 emissions by strengthening the cement kiln combustion process. Cemex UK's current success with AF usage is the new fuel handling system is now commencing operation and using green hydrogen in the production process, and once fully optimised, will have the capacity to operate at 100% with AFs. Presently Suez, the international recycling and waste company, has an MoU of 25 years with CEMEX since 2015.

Source: Cemex UK media center: "Cemex UK: innovations for fossil fuel phase-out." Published on 09 March 2021, https://www.cemex.co.uk/-/cemex-invests-us-25-million-to-phase-out-fossil-fuels-at-rugby-cement-plant-in-the-uk.

Middle East

Iran's Cement Industry Is Exploring Alternatives in the Midst of a Fuel Crisis

Iran is facing power outages due to a lack of natural gas supplies. As a result, cement plants are anticipated to store mazut as an alternative fuel in the coming days, according to Abdolreza Sheikhan, secretary of the Cement Industry Association. Mr. Sheikhan also mentioned that a summer power outage had previously resulted in a cement shortage and price increases in the market. As a result, he raised alarm about the possibility of simultaneous power and gas outages this winter. In such a case, the cement industry may struggle to meet winter cement demand.

Source: International Cement Review: "Iran's cement industry to prepare alternatives amid fuel shortage." Published on 03 November 2021, https://www.cemnet.com/News/story/171685/iran-s-cement-industry-to-prepare-alternatives-amid-fuel-shortage.html.

Iraq - RDF Usage Initiative by Gasin Cement

In the northern Iraqi city of Sulaymaniyah, Faruk Investment Group (FIG) has constructed a mechanical biological treatment facility.
The project intends to address the issue of unchecked municipal solid waste by processing it into refuse-derived fuel, offering an alternative fuel source for FIG-owned Gasin Cement Co (GCC) and minimizing the region's waste disposal impact.

Overall mechanical biological treatment facility in Sulaymaniyah can process 480,000 tonnes per annum(tpa) of MSW and produce 223,000 tpa of RDF. Around 300 tonnes per day (tpd) of RDF is transported to GCC by means of walking floor trailers. Due to the current usage of RDF proportion in the fuel

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mix of the cement plant of GCC, the heavy fuel oil (HFO) utilisation is reduced. The current scenario of thermal substitution rate from HFO by RDF is 40%. This project will have positive contributions towards climate by reducing 501,000 t CO_2 equivalent per year.

Figure 3: *The Mechanical Biological Treatment facility of Faruk Investment Group in Sulaymaniyah, northern Iraq, is designed to take and process 480,000tpa of municipal solid waste (MSW) and generate 223,000tpa of RDF.*

Source: Eggersmann Anlagenbau GmbH: "Gasin Cement's Road to RDF." Published on 19 October 2021, https://www.eggersmann-recyclingtechnology.com/fileadmin/media.

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