Feasibility Study on introducing a hybrid GHG Reduction Technology for the Cement Sector Using Green Climate Fund (GCF) in South Africa

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Research Institute of Innovative Technology for the Earth

UNFCCC-Climate Technology Centre and Network (CTCN)) Technology Assistance project

THE CEMENT SECTOR: TOWARDS SUSTAINABLE DEVELOPMENT GOALS

CONTENTS

1. INTRODUCTION: Who is the ACMP?

The ACMP acts as an umbrella body for six South African clinker and cementitious material producer companies, specifically guiding and representing their interests in the fields of

- environmental stewardship,
- health and safety practices, and
- community and stakeholder interaction

All members produce cement in **compliance SABS standards**

The ACMP's member companies include:

- ❖AfriSam: www.afrisam.com
- ❖Lafarge South Africa:www.lafargeholcim.com
- ❖NPC-: www.npc.com
- ❖Pretoria Portland Cement Company Ltd: www.ppc.co.za
- ❖Sephaku: www.sephakucement.co.za

ACMP Association of Cementitious Material Producers

ACMP- Communication partner of the WBCSD-CSI

Cement Sustainability Initiative

ACMP- Communication partner of the WBCSD-CSI

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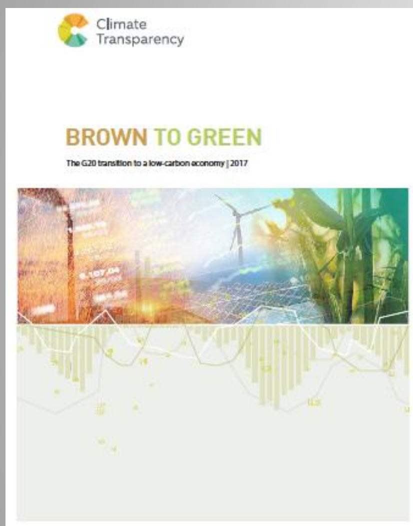
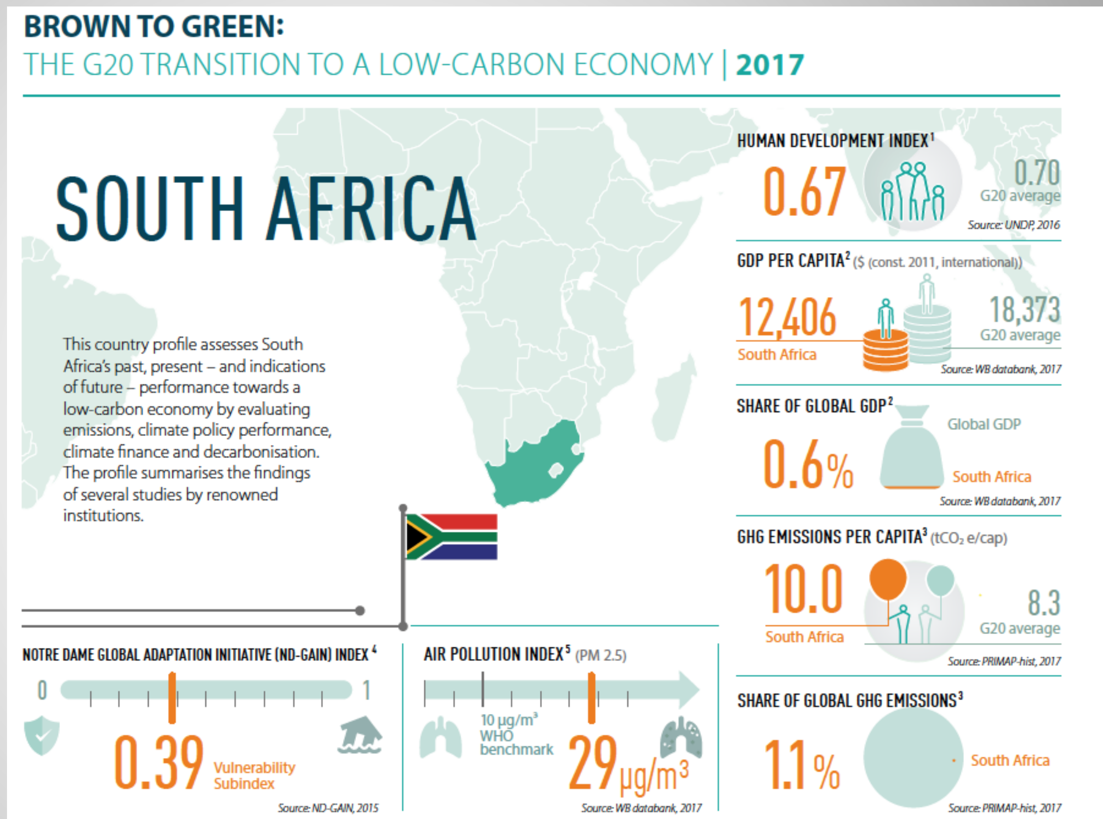
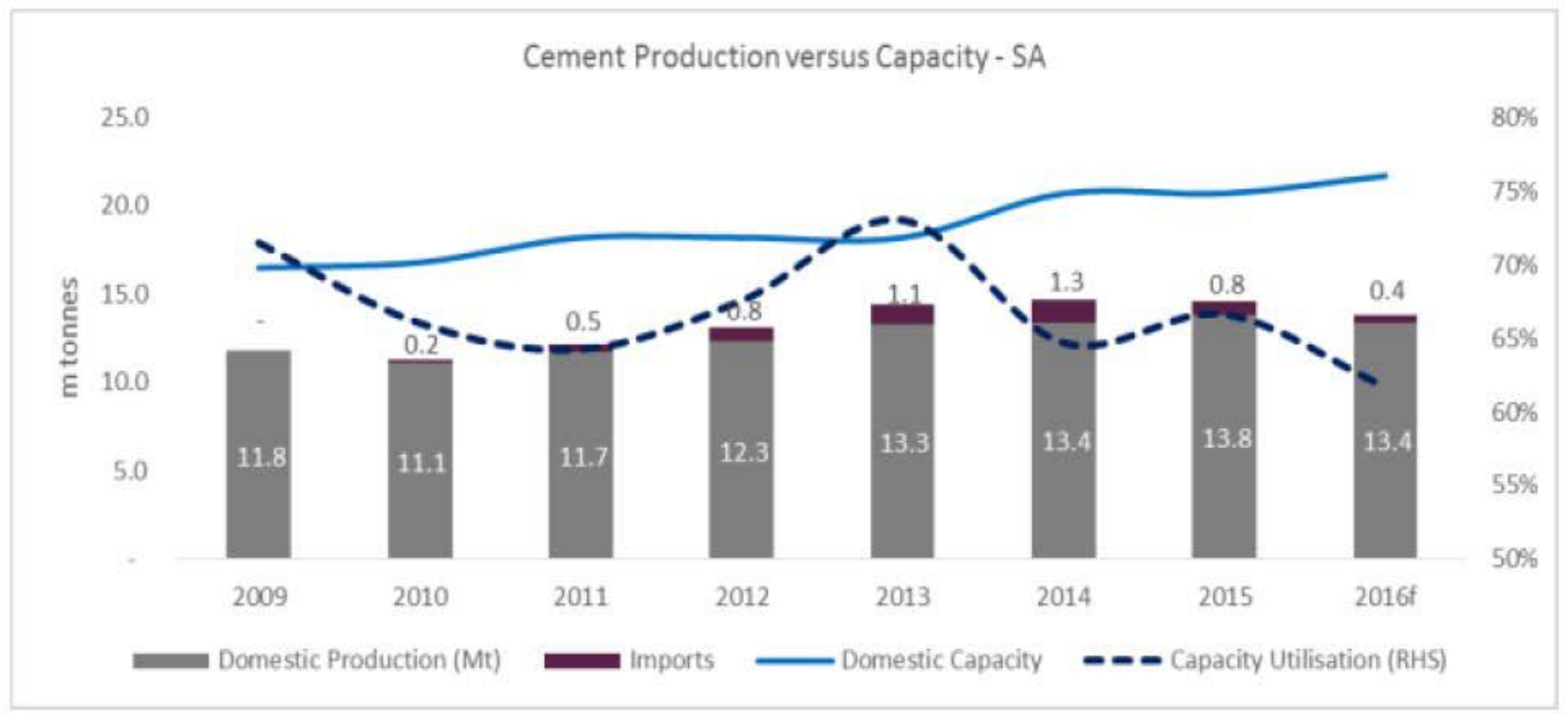
CONTEXT: SOUTH AFRICA





Climate transparency 2017: Brown to Green: the G20 transition to a low-carbon economy, Climate Transparency, c/o Humboldt-Viadrina Governance Platform, Berlin, Germany, www.climate-transparency.org. www.climate-transparency.org/20-climate-performance/g20report2

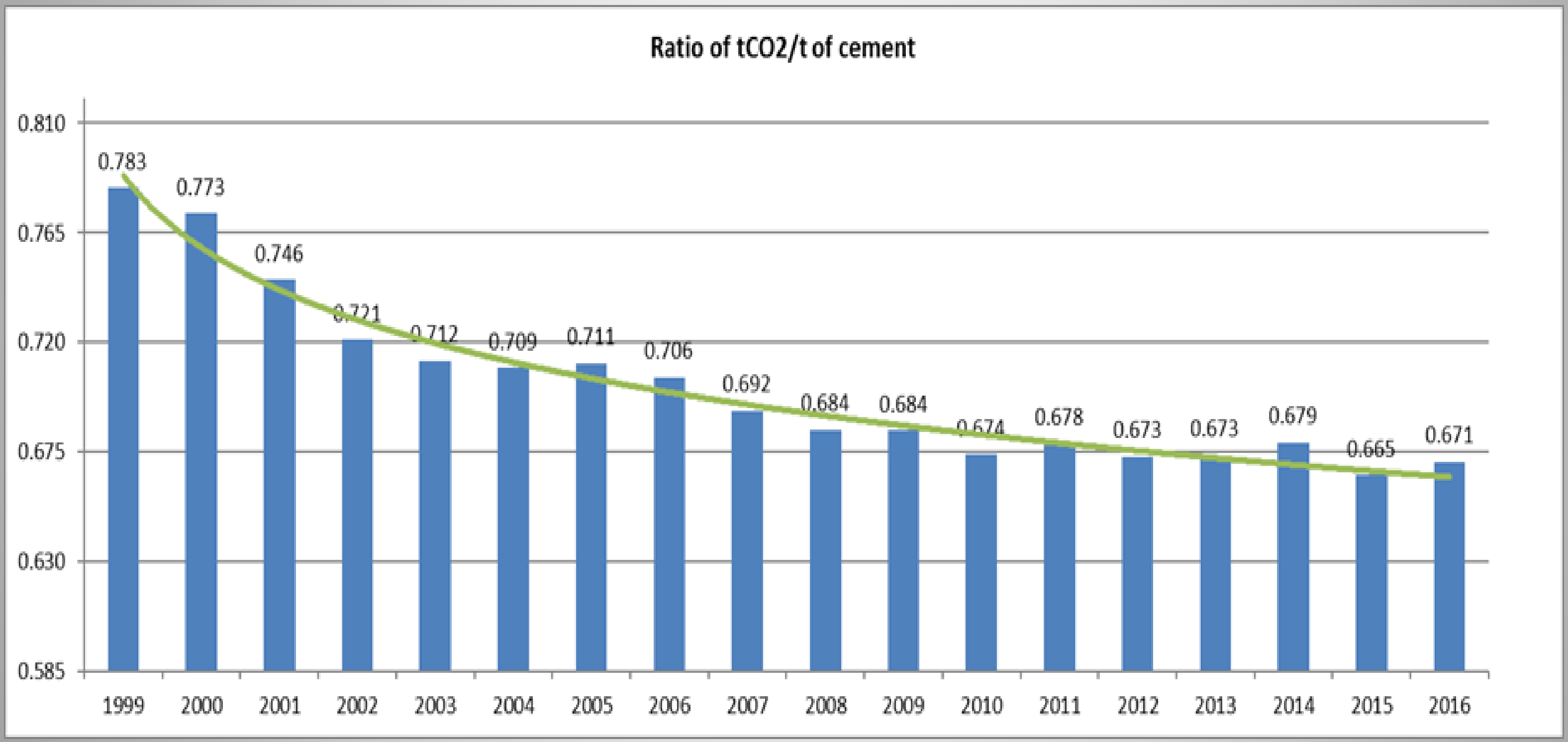
CEMENT PRODUCTION vs
INDUSTRY CAPACITY IN SOUTH AFRICA



Neil Brown& Richard Hasson. Electus Fund managers. Quartely strategy Note. October 2017.
http://www.electus.co.za/media/88880/electus_quarterly_strategy_note_october_16.pdf

2. GHG emissions profile: COMMITMENT TO APPROPRIATE RESPONSE TO CLIMATE CHANGE

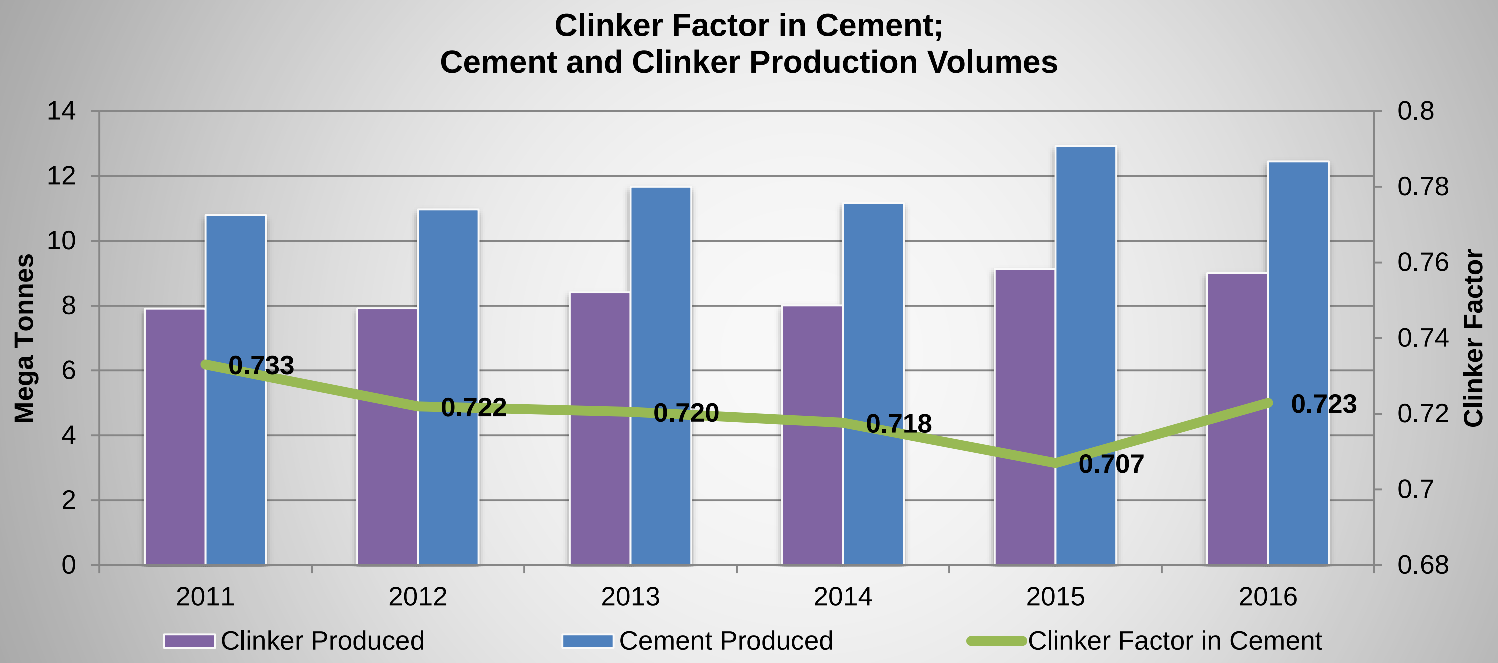
The cement sector has over the past years *proactively* addressed climate change concern as can be noted in Figure 1 below



ACMP members fully committed to responding to impacts posed by climate change.

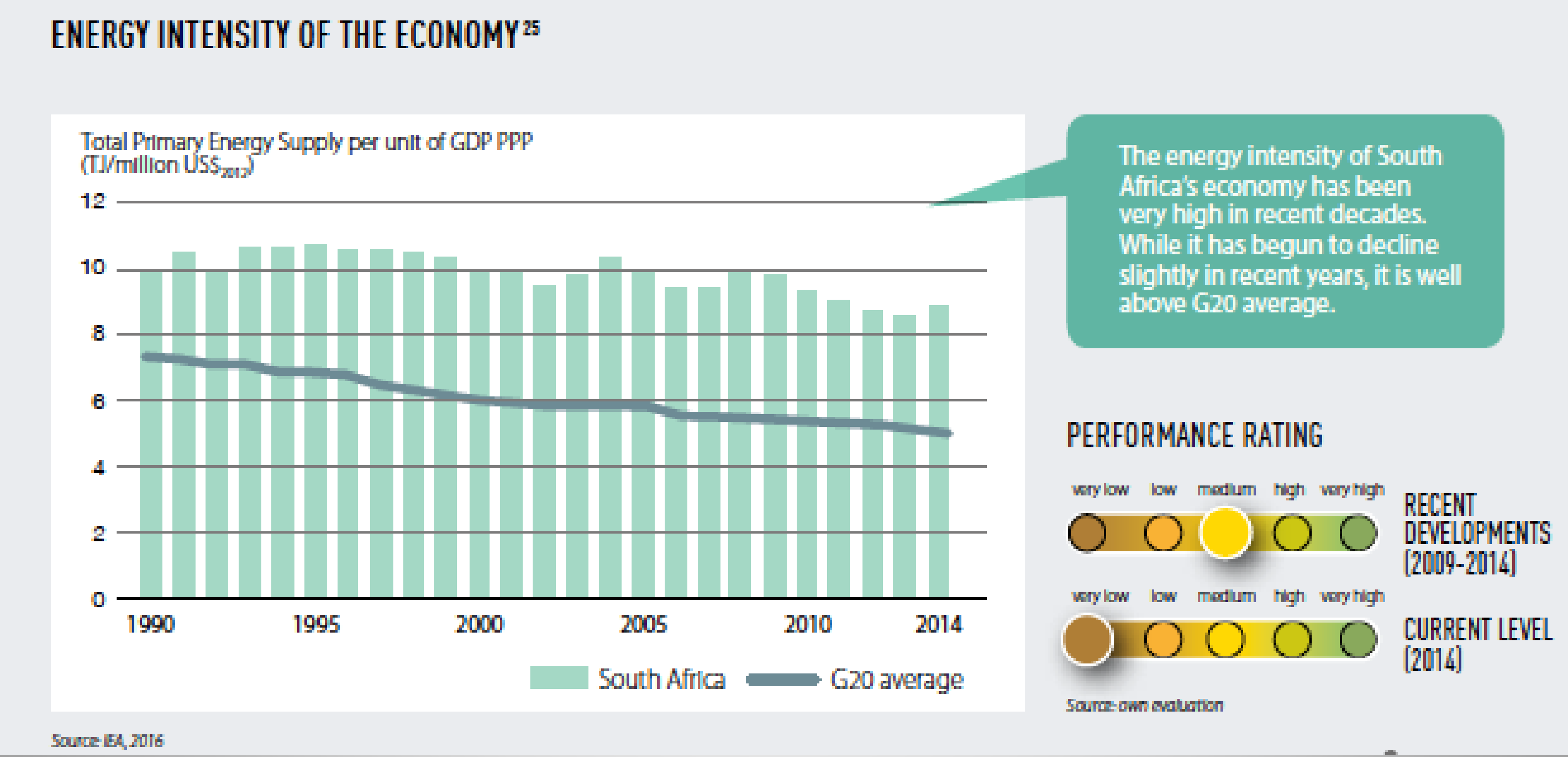
MORE CEMENT WITH LESS VIRGIN MATERIAL

- Extenders such fly ash and slag
- Improved milling and blending practices



"Getting The Numbers Right" (GNR) report for 2014: The Cement Sustainability Initiative (CSI)					
Global data		1990	2012	2013	2014
% Clinker in cement	%	83	74.7	74.7	74.5
Note: WBCSD Roadmap target for 2020: 74%: SOUTH AFRICA AT 72% IN 2016					

ENERGY



Climate transparency 2017: Brown to Green: the G20 transition to a low-carbon economy,
Climate Transparency, c/o Humboldt-Viadrina Governance Platform, Berlin, Germany,
www.climate-transparency.org. www.climate-transparency.org/20-climate-performance/g20report2

3. Feasibility Study on Introducing a Hybrid GHG Reduction Technology for the Cement Sector

- 2016 ACMP applied via NDE TO UNFCCC-Climate Technology Centre and Network (CTCN) for technical assistance
- CTCN approved the project and appointed RITE to support ACMP
- RITE: Research Institute of Innovative Technology for the Earth
  - R&D of industrial technologies that contribute to the conservation of the global environment and progress of the world economy
  - Based in Japan
- ACMPs experience on the application process:
  - ACMP members appreciates the support of the submitted proposal
  - CTCN application process
    - ACMP applied to CTCN via South Africa's NDE
    - CTCN appointed the Service Provider
    - The Service Provider informed ACMP of their appointment
  - Recommendation
    - Communication from CTCN:
      - Acknowledgement process
      - Application outcome: approval/rejection
      - Confirmation of the Service Provider appointed
      - Value of project
    - Confidentiality status of reports

2.2 TA Project Outline

1. Title :	• Substantial GHG emissions reduction in the cement industry by using waste heat recovery combined with mineral carbon capture and utilization
2. Purpose:	• To estimate significant GHG emissions reduction from the cement sector by using carbonation technique with waste concretes and concrete sludge • To find appropriate and marketable means to reuse byproducts from the carbonation process and estimate GHG abatement cost
3. FS terms:	One Year (December 28,2016 - December 28, 2017)
4. Members:	• RITE (CTC network member, Japan) • ACMP(key representative, RSA) • Local Partners: ACMP member company/ies, Concrete product manufacturer(s), DEA (Chemical and Waste Branch/Climate Change Branch) and South Africa National Energy Department Institute (SANEDI) • MCC Expert: Tohoku University • Cement & Concrete Experts: Taiheiyo Engineering Corporation and NIPPON Concrete Industries Co., Ltd. • Finance Expert: Mitsubishi UFJ Morgan Stanley Securities Co., Ltd.

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4. Technology Concept: hybrid of waste heat recovery & mineral carbon Capture and Utilization(MCC&U)

Resource Efficiency

Concrete Sludge

or

Concrete Wastes

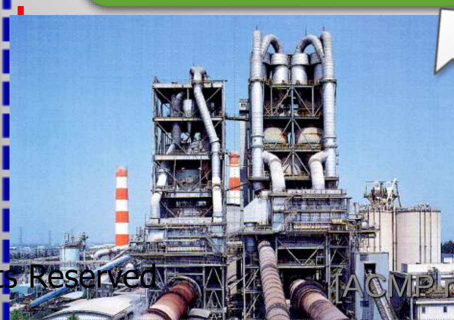
or

Industrial Wastes containing Alkali Earth Metal (e.g. Blast Furnace Slugs, etc.)

Hybrid low carbon technology

MCC&U plant (reactor)

Waste Heat Recovery



CO_2-rich Exhaust Gas from Cement Kiln

GHG reduction due to Carbon mineralization

$CaCO_3$

Remediation Agents: Adsorbents/Neutralize

Resource Efficiency

Reuse as construction materials, painting, glass, ceramics, paper, rubber, resin, asphalt filler, food, pharmaceutical , colorant, etc.

Removal of toxic materials from wastewater and soil, e.g. **phosphorus** and arsenic and reuse the materials

Resource Efficiency

Step A CTCN Technical Assistance

RITE: APPOINTED BY CTCN

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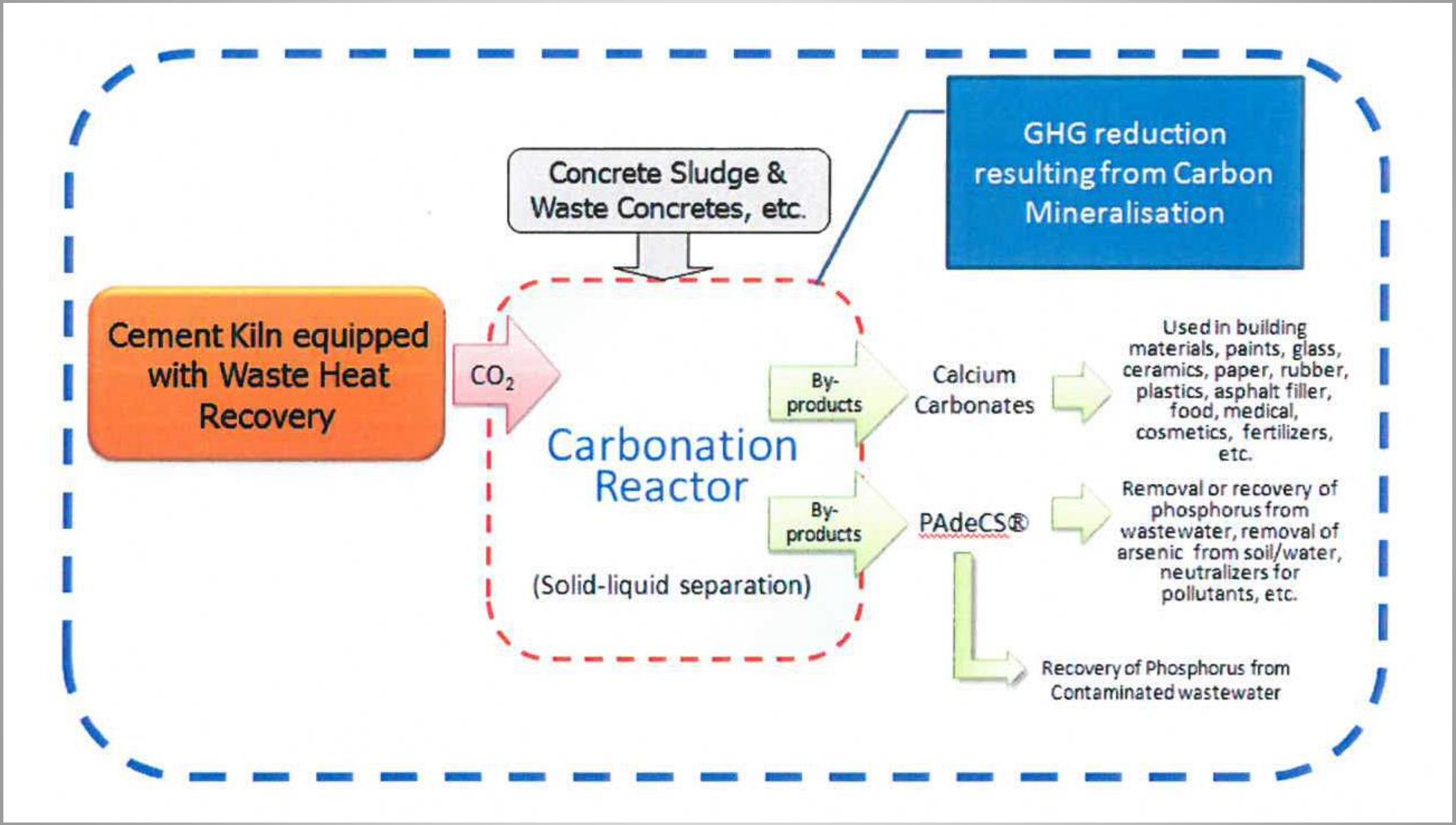

Carbon mineralisation

4.3 Carbon Mineralization

Ca and Mg from Concrete Sludge + $CO_2 \rightarrow$ Carbonates ($CaCO_3$, $MgCO_3$)

Advantages:

1. Huge potential for sequestration
2. Stable sequestration
3. Safety reaction process

5. RESULTS:
MITIGATION POTENTIAL: WHR

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Table 4.11 Total CO_2 reduction by using proposed hybrid low carbon technology at target site

Emission	Emission Source + emissions - reduction		Target Site ($t\text{-}CO_2/yr$) Type I 200 Km	Type II and II_{add} 100 Km	Type III 50 Km
Scope I	WHR	(-)	0	0	0
	MCC	(-)	38,400-39,700	32,400-38,000	89,400-100,300
	U	(-)	Depending on volume of cement production (up to 5%)		
Scope II	WHR	(-)	37,800	26,900	37,800
	MCC	(+)	1,700-2,700	1,100-1,800	3,900
Scope III	Transport	(+)	32,600-33,700	12,200-13,100	1,128

Table 3 Type of target plant

Target Site	Scenario (MCC)	Scenario (U)
Type I	Cement plant size is full-scale (kiln capacity of over 3,000 t/d) 30% of concrete sludge from ready-mixed concretes plants and waste concretes from concrete product plants is transported an assumed distance of 200km.	$CaCO_3$ produced from MCC is added to portland cement as U_{mac} (replacing percentage of the cement)
Type II	Cement plant size is medium-scale (multi-kilns with the total kiln capacity of approximately 3,000 t/d) 20% of concrete sludge from ready-mixed concretes plants and waste concretes from concrete product plants is transported to the plant up to 100km.	
Type II_{add}	Cement plant size is medium-scale (multi-kilns with the total kiln capacity of approximately 3,000 t/d) Additional input material such as recycled fine aggregates from demolished concrete near the plant is included	
Type III	Cement plant size is full-scale (kiln capacity of over 3,000 t/d) Concrete sludges are not available near the plant but an alternative material such as lime dust is used. (Its transport distance is within 50km)	

5. RESULTS: MITIGATION POTENTIAL WHR: AIR WOULD BE PREFERED

Table 1 Potential power generation and CO_2 emissions reduction at target plants

Annual Power Generation/ CO_2 emissions reduction	Cooling system	Unit	Target Plant	
			Type I (Full-scale)	Type II (Medium-scale)
		t/d	more than 3,000 (single kiln)	around 3,000 (multi-kilns)
Power to be Generated	Water	MW	5.4-7.6	3.1-5.1
Effective Power Generation		MW	4.9-6.8	2.8-4.6
Power to be Generated	Air	MW	5.3-7.4	3.0-5.0
Effective Power Generation		MW	4.7-6.7	2.7-4.5
Emission factor for electricity		t-CO_2/MW	1	
Average annual CO_2 emissions reduction		t-CO_2/year	37,790	26,910

Table [illegible] Scope I, National CO_2 emissions reduction by the hybrid facility

Technology		CO_2 Emissions Reduction Potential (t/yr)	
WHR installation		0	565,340-588,100
MCC&U installation	MCC	224,240-244,200	
	U	341,100-343,900	

Table [illegible] Scope II, National CO_2 emissions reduction by the hybrid facility

Technology	Power (MW)			CO_2 Emissions Reduction Potential (t/yr)
	Generated	Consumed	Net	
WHR installations	185,800	18,600	167,200	64,300
MCC&U installation	0	102,900	-102,900	

6. ALTERNATIVE GREENHOUSE GAS EMISSION PATHWAYS FOR SOUTH AFRICA DEPARTMENT OF ENVIRONMENTAL AFFAIRS. DRAFT 9 MARCH 2018 PREPARED BY THE GREEN HOUSE AND DNA ECONOMICS)

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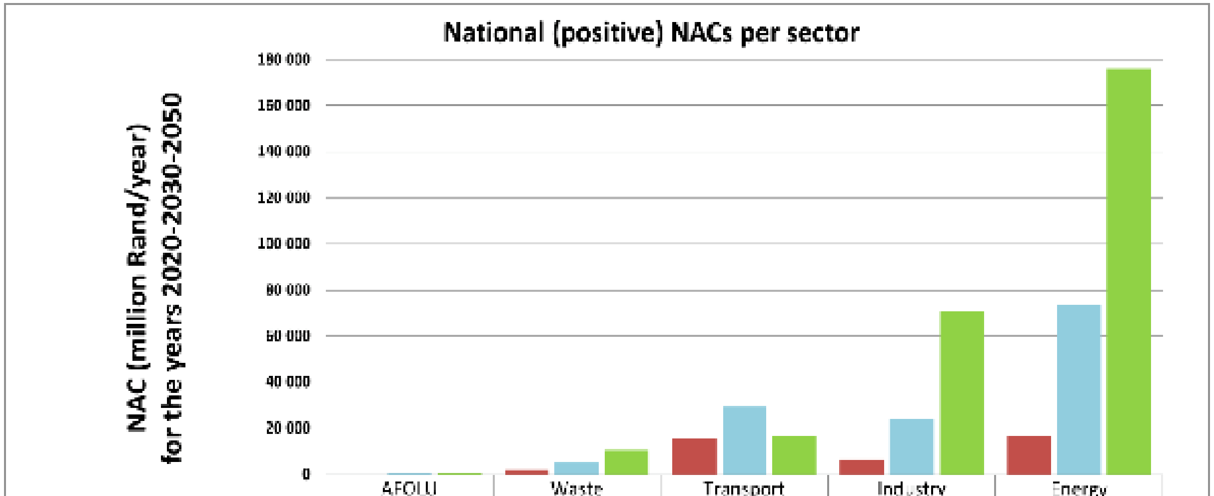
ENERGY LANDSCAPE	Impact*	TRANSPORT	Impact*
□ Decentralised generation with storage	++	□ Rapid modal shift	++
□ Increased shift to gas	+++	□ Electric vehicles – moderate penetration	++
□ Increased utility-scale renewables with storage	n.d	□ Electric vehicles – high penetration with CNG	+++
□ Early decommissioning - some power stations	++	□ Work from home	++
□ Early decommissioning - all power stations	++++	□ Telepresence	+
□ Decommissioning of CTL	++++	□ Car sharing	+
□ Biomass energy	+	□ Increased biofuels	+++
□ Energy from Waste	++	□ Improved fuel efficiency	++
		□ Smaller vehicles	+
BUILDINGS AND CITIES		□ Optimised logistics	+
□ Urban densification	++	□ High speed passenger rail	+
□ City planning – nodal development	++	MATERIALS AND WASTE	
□ Non-motorised transport	+	□ Reduced food waste	++
□ Intelligent buildings	+	□ Increased recycling	++
□ Green roofs	+	□ Alternative cement	++
□ Retrofitting	+	□ Alternative building materials	+
□ Smart glass	+	□ Composting	++
AGRICULTURE AND LAND		COMING ATTRACTIONS	
□ Plant-rich diet	+++	□ CCS/CCU – industry	+++
□ Nutrient management	+	□ CCS/CCU – power generation	+++
□ Managed grazing	+++	□ Autonomous vehicles	++
□ Improve agricultural value chain efficiencies	+	DEMOGRAPHICS	
		□ Slowing urbanisation	++
		□ Curbing population growth	+++

Rating: Cumulative emission reduction between 2015 and 2050			
++++	+++	++	+
> 1,000 $MtCO_2e$	100 - 1,000 $MtCO_2e$	10 -100 $MtCO_2e$	1 - 10 $MtCO_2e$

INDUSTRY SECTOR GHG

- **Industry sector account for 8.1% of South Africa‘s total emissions (DEA, 2014a, p. 37)**.
- The national net annual cost (NAC) for South Africa is estimated at R 40 billion/year for the year 2020



	AFOLU	Waste	Transport	Industry	Energy
+ NAC (Million R/year 2020)	153	1 869	15 568	6 569	16 653
+ NAC (Million R/year 2030)	657	4 859	29 339	24 022	73 663
+ NAC (Million R/year 2050)	685	10 284	16 125	70 704	176 094

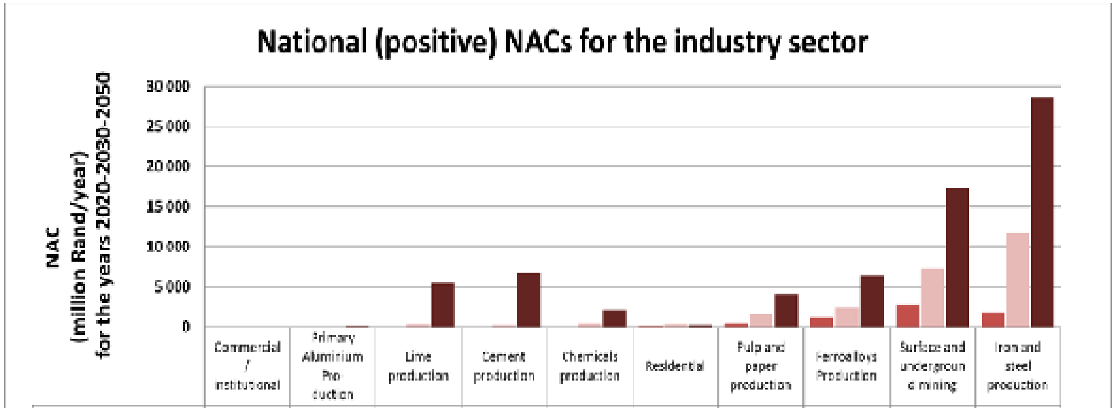
Figure 4.16: National (Positive) NACs per sector for the Years 2020, 2030 and 2050 (DEA, 2014b, p. 105)

Note: Largest share by energy sector followed by small proportion in the industry sector

South Africa’s Third National Communication under the United Nations Framework Convention on Climate Change. Department of Environmental Affairs. 2017. Pretoria. March 2017

INDUSTRY SECTOR:
The national net annual cost (NAC) for Industry

South Africa's Third National Communication under the United Nations Framework Convention on Climate Change. Department of Environmental Affairs. 2017. Pretoria. March 2017



	Commercial / institutional	Primary Aluminium Pro-duction	Lime production	Cement production	Chemicals production	Residential	Pulp and paper production	Ferroalloys Production	Surface and underground mining	Iron and steel production
NAC (Million R/year 2020)	- *	14	43	43	68	138	495	1 251	2 706	1 810
NAC (Million R/year 2030)	- *	28	328	166	453	221	1 528	2 358	7 335	11 704
NAC (Million R/year 2050)	- *	103	5 436	6 761	2 173	178	4 072	6 310	17 206	28 464

** The measures considered have a negative marginal abatement cost in this year and therefore result in a negative NAC value which is not plotted in this graph.*

Figure 4.22: National (Positive) NACs in Million Rand per Year, per Subsector in the Industry Sector for the Year 2020, 2030 and 2050 (DEA, 2014b, p. 105)

Note:
Cost for the implementation of technologies increases significantly with time.

In 2050, investments in the cement production subsector are estimated to displace the ferroalloys production subsector from its position in the top three highest NACs in both 2020 and 2030

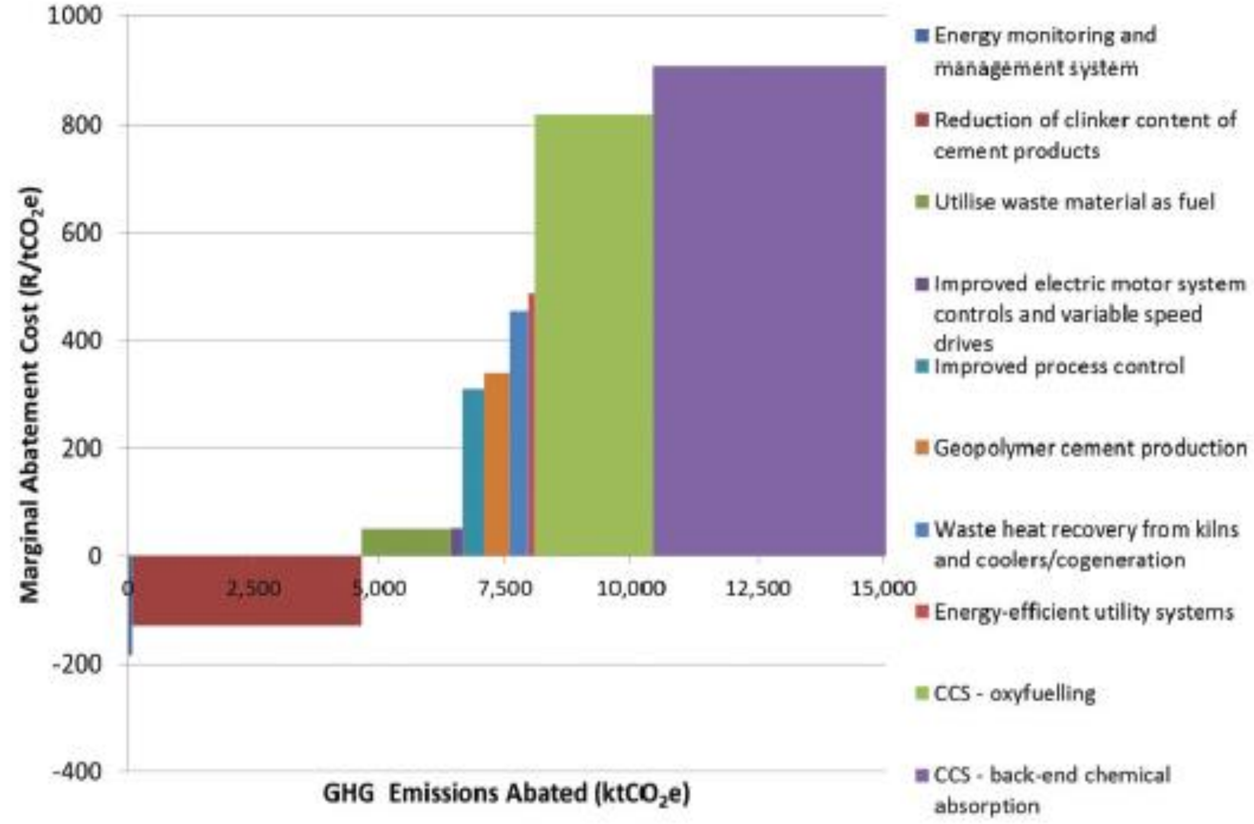


Figure 20: Cement production MACC for 2050

WHR-MCCU implementation in South Africa: COST IMPLICATIONS/VIABILTY

- WHR installation
  - Current initial investment costs for WHR prohibitive
  - Renewable energy costs dropping (possible consequence: WHR may thus not be competitive)
    - Recommendation: Financial assistance and incentives/subsidies to implement
- MCCU installation
  - Concrete sludge from centrifugal moulding is not available in RSA
    - RITE assessed possible ways of generating carbonates using recycled fine aggregates from demolished concrete
    - Considered identification of other waste streams containing calcium and magnesium compounds
    - Low carbon cements in future will decrease availability of effective calcium in concrete waste
- By Products from MCC
  - Require further assessments for acceptance
- Project only feasible if the by-products can be sold at a high price
  - Further marketing of by products must be a priority to support the introduction of the MCCU technology

WHR-MCCU implementation in South Africa: FINANCIAL ASSISTANCE

- Potential GHG reduction of 7.5-7.7% possible in RSA
- GCF support may be appropriate
  - Supports SDG goals:
    - #13: reduce GHG
    - #9: innovation
    - # 12: responsible consumption

8. Recommendation 1

BENCH SCALE MCCU REACTOR:

ASSESS THE COST EFFICIENCY OF THE TECHNOLOGIES

1. Produce $CaCO_3$ and ERA using concrete/fine aggregate wastes using stationary or mobile type
2. Assess performance in comparison with commercial remediation agents.
3. Other activities:
   - Operator training and the development of by-product applications,
   - R&D on the use of demolished concretes as an alternative input material to increase the total CO_2 emissions reduction.

ERA: Environmental remediation agent delivered from MCC&U technology

Theoretical data: to be confirmed with pilot plant:

Produce $CaCO_3$ and ERA using concrete/fine aggregate wastes

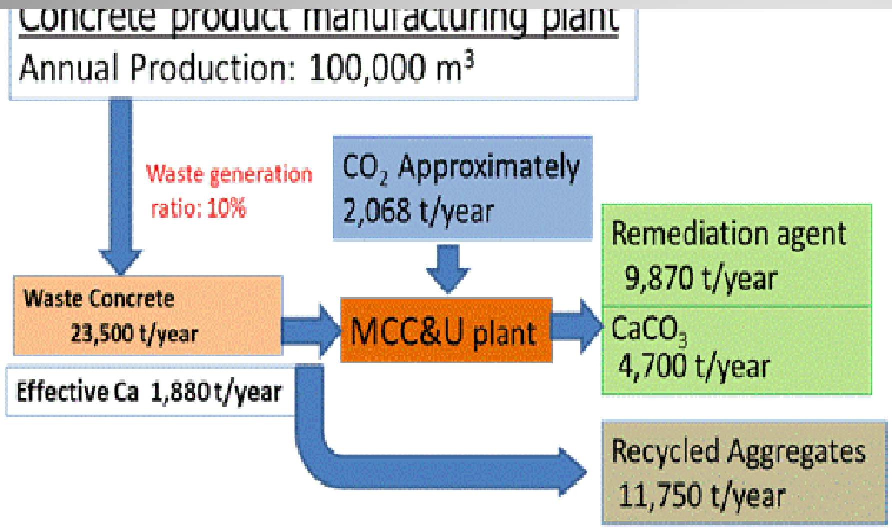


Fig. 4.4 CO_2 captured by MCC&U at a typical concrete product plant

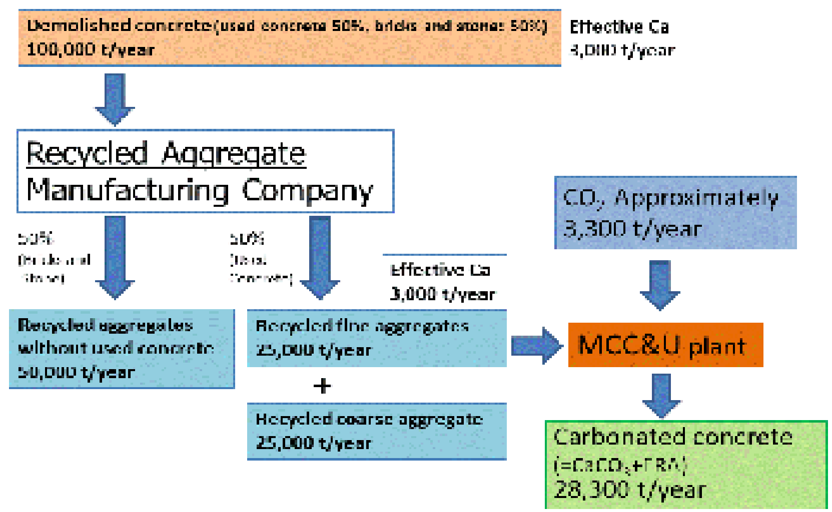


Fig. 4.5 CO_2 captured by MCC&U at the recycled aggregate manufacturing plant

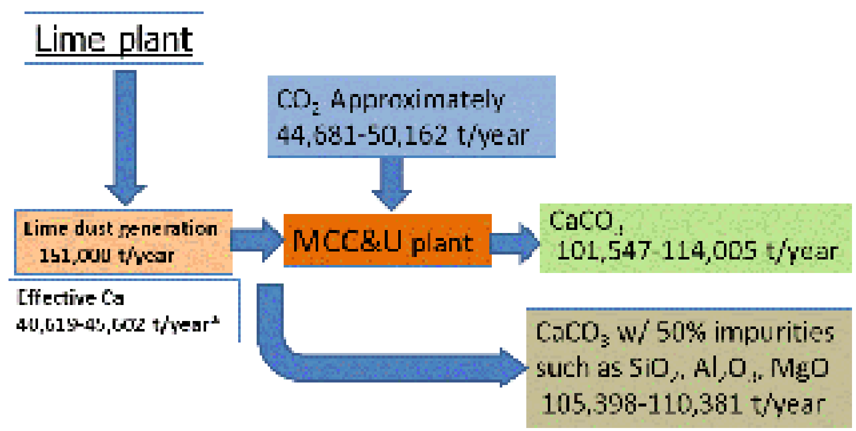


Fig. 4.6 CO_2 captured by MCC&U at the lime plant

Recommendation 2

FINANCIAL ASSISTANCE

Support innovative technology

- Demonstration pilot:

  Innovative technologies such as MCC&U need to convince financiers or any risk takers to scale-up the project to a commercial level.

- Challenge:
  - Bench-scale plant for the MCC&U: approximately USD 20 to 40 million(includes training).

Recommendation 3

MARKETABILITY OF RECYCLED BY-PRODUCTS for national production of CO_2

By-products:

- $CaCO_3$: about 4 700 tons per plant (national: about 500 000)
- ERA: pilot plant to advise (sample from Japan tested: used concrete sludge ***not*** fine aggregate)

- **By products**
  - Reduce CO_2 in cement production
  - Neutralising agent
  - Treatment of acid mine drainage (AMD)
    - Both of the commercial neutralisers for AMD, $Ca(OH)_2$ and $CaCO_3$, are almost entirely domestically sourced products.
    - However, the $Ca(OH)_2$ market size for AMD treatment seems to be limited due to cost constraints but may increase if a competitive ERA price is applied (CGS)
  - Recovery of phosphorous-bearing wastewater from industrial and urban activities.
    - Ratio of ERA required to recovered phosphorus from water is approximately 10:1
    - If ERA is economically used for sewage sludge treatment, the phosphorus can be recovered as resources (UCT)
    - Potential to produce calcium phosphate from diverted urine using the ERA since high concentration phosphorus is contained in urine collected at urine diversion dehydration toilets (UCT).

- **Other applications**:
  1. Asphalt fillers, fillers for paper and plastic manufacturing processes ,etc
     - These high-end applications require precision in their specifications,
     - Their prices vary
     - Difficult to estimate the market size. Since

  1. ERA contains minerals such as ettringite: can be used to remove heavy metals and arsenic from contaminated soil and water as a substitute for $Ca(OH)_2$.

9. CONCLUSION

- WHR-MCCU introduction has significant GHG emissions reduction potentials
- Assessing the cost efficiency of the technologies
  - Introduction of the technologies requires financial support and incentives/subsidies
  - GCF funding should be considered
- Marketability of recycled by-products from local concrete wastes
  - Further work required to promote the use of the by products form waste concrete as well as waste water
- Business plan for the project implementation in RSA should be developed.
  - Possibility of public/international funding for the implementation must be considered

Acknowledgements:

1. Climate Technology Centre and Network (CTCN)) Technology Assistance project
2. Research Institute of Innovative Technology for the Earth
3. Department of Environment draft and/or final documents

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Thank you!