Independent Mid-Term Review

of the

Low Carbon Cement Project (LCC)
(Phase 2)

Implemented by

École Polytechnique Fédérale de Lausanne (EPFL) and Cementis GmbH

on behalf of

Swiss Agency for Development and Cooperation (SDC)

Report

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1. Introduction

An independent review of the present status of Phase 2 of the LCC project was conducted between July 15 and November 1st, 2019. Mandated by the Swiss Agency for Development and Cooperation (SDC), a team of independent consultants (called the Review Team hereafter – see Chapter 5a) performed an in-depth analysis of available documentation, a comprehensive series of interviews with involved stakeholders in the project and a few on-the-ground technical visits to pilot plants and laboratories where initial and enhanced tests were performed. These visits were also undertaken with policymakers and standard-setting entities to complete the analysis of the potential of the LC3 cement in the future and its capability to become a mainstream type of cement in the market.

For more information on the project itself, the paragraph 3 – Background of the LCC project, provides with all necessary information to understand the context of that independent review.

This report provides the conclusions of the analysis, of the interviews and the visits performed by the Review Team. Although all gathered information has been recorded, analysed and taken into account in the subsequent analysis performed by the Review Team, elements provided in this report are not directly associated to any specific person interviewed or met during the review. They are provided to SDC as the independent views and recommendations of the Review Team and should be considered as such by SDC in their future decision-making process for the potential next steps of the project.

2. Executive Summary

This document presents the final report of the independent review of the ongoing phase 2 of the Low Carbon Cement (LCC) Project, which is supported by the Global Programme Climate Change and Environment (GPCCE) of the Swiss Agency for Development and Cooperation (SDC). The goal of the review is to independently evaluate the overall performance of the LCC Project, including the impact, outcomes, outputs, partnerships, processes, and to provide recommendations for potential future support by SDC. The review is based on the OECD-DAC criteria, namely relevance, effectiveness, efficiency, impact and sustainability. The assessment and the recommendations are based on documents provided by SDC and project partners, telephone and face-to-face interviews, and on project visits to India, Cuba and Guatemala. The Review Team leader also conducted some interviews and cross-fertilizing discussions between different stakeholders during the 36th Technical Congress of FICEM (the Inter American Federation of Cement) in Punta Cana (Dominican Republic)

Overall, the review team concludes that the project is well on track towards the overall project goal for phase 2, which is to establish Limestone Calcinated Clay Cement (LC3) as a reliable, viable and green cement. The LCC project partners (Swiss, Indian and Cuban research institutes and Swiss-based consultancy Cementis) have generated a strong body of scientific and technical evidence and engaged in disseminating this evidence. Today, most of the cement producers in various parts of the world are aware of LC3 and several of them are considering the adoption of LC3 in their operations. The Technical Resource Centers (TRC) in India and Cuba are providing a sustainable structure to assist cement companies in India, Africa and Latin America on technical questions related to LC3 and their expertise was deemed very helpful in conversations with actual customers.

The status of the **outcome-wise achievements** for phase 2 can be summarised as follows:

Outcome 1 - The technical, economic and ecological viability of LC3 is scientifically investigated and validated: In general, the project has successfully investigated and validated the viability of LC3. Results were disseminated through the relevant literature as well as on conferences and information days. However, certain stakeholders expressed a number of remaining concerns, namely on early strength of LC3, its long-term durability, and the use of additives, where they would require further support from the TRC.

Outcome 2 - LC3 is produced by pioneering cement companies and showcased in representative construction projects in India, Cuba and selected other countries: The achievement of this outcome is on track, but not fully achieved yet. Pilot productions at small scale have taken place in Cuba, Guatemala and India. In addition, a production line in Ivory Coast is expected to go online before the end of phase 2. With an annual LC3 production of 750,000 tons, this plant would surpass the project goal of 1000 tons by several magnitudes. Finally, major international cement producers indicated their willingness to invest in calcined clay cement production in several countries over next few years, notably in Europe and Africa.

Outcome 3 - A conductive regulatory environment is created for upscaling the production and application of LC3 through standards, certification and policies: This outcome has not been fully achieved, despite the fact that the documents have been prepared diligently by the project team. As mentioned in the risk analysis to the credit proposal, the adoption turned out to be a slow process that is expected to take an additional 1-3 years. In India, a patent issue, which could be resolved in the meantime, has also contributed to the delay. An excessive pressure to finish the process as quickly as possible would come along with tougher limitations related to the applicability of LC3, thereby not realizing the full potential of this technology.

The evaluation of the project based on the OECD-DAC criteria can be summarized as follows:

Very high relevance: LC3 offers a credible pathway to deliver a substantial mitigation of CO_2 emissions in the global cement sector (offering a sustainable opportunity to reduce the clinker/cement ratio), and to preserve resources for raw material (limestone and clinker substituents). Emerging carbon prices and their likelihood to further develop, taxation schemes and emissions trading systems can further add to the development potential of LC3. In addition, with the almost infinite availability of clay, LC3 provides a sustainable alternative for development of building and infrastructure. Its long-time strength and performance, including with regards to resistance to potential corrosion in coastal areas, it provides a resilient type of product, at an affordable cost that should develop in countries prone to climate change impacts and particularly islands and developing countries.

High effectiveness: The LCC project has formed a strong foundation for future industrial deployment of LC3. Initial production (so far limited) and tests performed (India, Cuba, Guatemala, Peru) have confirmed the research findings and demonstrated positive results for multiple applications. The technical, economic and ecological viability of LC3 has been investigated by different stakeholders and can be considered as reasonably validated through the various tests done by the TRCs and the pilot companies; The involvement of ceramics experts is essential for the future of the project. At this point in time, in countries where the existing standards need to be set up or updated, some external conditions (patent in India, low involvement to date in Europe) have slowed down the process which did not deliver as much as expected.

High efficiency: The project used the given resources in an efficient manner for positioning the subject at national and international initiatives and to demonstrate its applicability at the level of R&D. However, more efforts are needed to materialize the final goal of establishing LC3 as mainstream cement, mainly through enhanced communication and information sharing with a large variety of stakeholders, such as major cement manufacturers in other target countries, standard-setting bodies, governments, machine and additive manufacturers and potential buyers of LC3. The identification of the most impactful international fora for such stakeholders will be instrumental, as well as the composition of teams with a dedicated focus on policy advocacy, marketing and practitioners will be a key success factor for building on the existing sound technical evidence.

High impact: The strong body of scientific evidence generated by the project and the high visibility of the project in the cement sector are crucial for the adoption of LC3 by global and national cement companies. Already, a good knowledge sharing activity has been undertaken and LC3 cements are now high on the innovation agenda of many global and local cement producers. The achievements reached in about 6 years since the beginning of the LCC project is remarkable and recognized by many in the global cement sector. A series of conducive factors (raw material strategy, cost and CO2 reduction, social benefit) as well as some remaining hindering factors (inexistent standards and codes, lack of know-how on clays, bad perception and lack of knowledge on clay's performance) have been identified as potential solutions to develop through the remaining part of phase 2 and through a potential phase 3.

High sustainability: The potential of the product itself is very high in terms of sustainability. However, at this point in time, the project still lacks the full and complete achievement of outcomes 2 (large scale pilot production) and 3 (standards, policies and certification). If discontinued at the end of Phase 2 in May 2020, the project runs the risk of LC3 remaining a niche product in very specific contexts for the coming years, thus minimizing the benefits of having undertaken and supported the first two phases.

Based on the above analysis, the review team has elaborated a series of recommendations for the remaining part of the project's phase 2. Following are the **main recommendations for** the remaining months of **phase 2**:

- Technical Resource Centers to maintain their active role of addressing producers' concerns related to LC3, particularly on early strength, long-term durability and additives; limited additional test could be envisaged but thorough explanations and communication on the existing knowledge should be emphasized.
- Technical Resource Centers to support the commissioning of the planned pilot production sites and corresponding technical challenges in the initial phase.
- Project team to document project learnings and key data gathered from the pilot phases and the first industrial production campaigns and make sure that SDC gets the necessary credits on these materials, where applicable.
- Project team to develop facts and figures for (non-scientific and non-technical) policy makers as advocacy arguments
- SDC to initiate the preparation of a subsequent and final phase 3, including the identification of the appropriate project setup and project partners. The current project team, its technical capabilities and experience should be involved in the new set-up in a context to be defined by SDC.

The review team further recommends initiating the planning of a third and last project phase in order to ensure the sustainable establishment of LC3 as a reliable, viable and green cement at global scale. The focus of the third and final project phase is to catalyze business deployment. In other words, a third phase will have not only to carry-on the project with appropriate financial support (to be defined in terms of volume and source) but also to accelerate and scale-up the elements of the project. The project needs to move towards a holistic support to real industrial-scale deployment in order to deliver identified environmental, economic and social benefits.

Four main work packages are recommended to support Phase 3:

1. Support standardization processes: Enabling standards are crucial for future deployment. One should define clear action plans in the various target countries (e.g. India) to ensure a successful outcome of standardization processes, considering active engagement with most relevant local stakeholders (example of the NCB in India). In parallel, adapting construction/building codes to recognize the existence and potential of LC3 should also be considered, with a clear communication to raise awareness and build capacity towards the community of architects, builders and developers.

2. Engage with technology suppliers and admixtures producers: So far, the project has focused on the cement producers in its efforts to disseminate LC3 and enhance initial production. For large-scale business deployment, producers need to purchase adequate equipment and admixtures that are suitable and specific for LC3. To overcome this potential barrier, we recommend engaging with manufacturers of admixtures and suppliers of production equipment. Sika, as one of the leading producers of admixtures could also add Swissness to the project, in line with SDC's strategy to engage with the private sector and promote Switzerland's added value in its projects.

3. Enhance awareness, share knowledge, build reputation: As of today, a lot of tests have been carried out to identify the various characteristics of LC3 and its possible application in concrete and concrete-based products (buildings and infrastructure). These tests have been carried out in different types of countries and with different types of clay. Although a few minor additional tests might be needed, on a case-by-case basis, particularly to clarify some concerns of projects for which suboptimal conditions were tested, the review team consider that sufficient knowledge and know-how has been established and that the focus should now be shifted to sharing this information to a wide group of stakeholders. One key target of this exercise would be to foster demand for LC3 and LC3-based products.

4. Develop and implement high-level advocacy: The active support of public authorities and financial institutions is essential to boost deployment. An active and consistent advocacy

approach should target these 2 groups of stakeholders in the various countries where the project operates and where some development potential has been identified.

The required set of skills to design and execute Phase 3 activities is significantly broader than those mobilized during the first 2 phases. Ideally, in each of the key regions, a practitioner with strong local reputation in the cement/construction sector should lead a strong team encompassing public advocacy, practitioners, marketing and technical profiles. In other words, the Review Team proposes to build on the experience of the TRCs, which should become LC3 Resource Centres. A global team should coordinate efforts and provide adequate support to local teams in terms of technical knowledge, facts, figures and interactions with international stakeholders. This team should bring together individuals with different backgrounds and dispose of the relevant network including policy and standard makers, cement producers, machinery suppliers, admixtures producers and potential LC3 buyers. In certain conditions and applications, it would also be essential to address and convince the final user (the people who occupy the buildings and use the infrastructure) to enhance the acceptability of LC3.

The members of the review team would like to thank all partners and counterparts for their availability and commitment to facilitate this review, for the warm welcome during the field visits and the professional support offered by SDC, EPFL in Switzerland and UCLV in Cuba.

3. Background of the LCC project

Cement is a vital input to concrete, which in turn plays a fundamental role in the construction of most modern buildings and of infrastructure, from roads to dams, airports to wind turbine bases. Few people realize that concrete is, in fact, the most used man-made material in the world, with three tons used annually for each man, woman and child. Its superior properties of strength, durability, thermal mass, affordability and abundance of raw materials, make it the material of choice for many purposes.
As such, it is an essential element for the sustainable development of our modern civilization, providing a material of choice for decent, affordable and resilient housing, particularly for fast growing countries and regions and it also forms the basis for the foundations and main infrastructure of decarbonated energy solutions (hydraulic, wind, nuclear…). Current global demand of about 4.1 billion tons per year is forecasted to grow to 4.7 billion tons by 2050[1], mainly driven by the demand from developing countries (demand for cement in India and Africa is likely to more than triple over the next 35 years)[2].

However, despite important improvements over past decades, cement manufacturing remains a CO_2 intensive process, contributing to enhancing climate change. The production of Portland cement (the predominant current cement type) entails the heating of ground limestone ($CaCO_3$) to an extreme temperature (chemical reaction happening at 1450°C) in kilns to produce calcium oxide (CO) with CO_2 emitted as a result. While process emissions from the production of cement releases 2.1 Gt of CO_2 per annum, the heat input to cement production currently generates roughly 1.3 Gt of CO_2 per annum and the manufacturing also causes indirect emissions from electricity used to operate machinery. Accounting for both the direct and indirect emissions, CO_2 emissions from this industry reach 3.8 Gt per annum[3]. Cement is responsible for around 7 per cent of global carbon emissions. If the cement industry were a country, then it would be the largest carbon emitter after China and the US. Realising the sustainable transition of the 2°C Scenario (2DS) implies a significant reduction of the global direct CO_2 emissions by 24% compared to current levels by 2050 still with the expected increase in global cement production.

This diagnostic creates two main challenges for the future, if we want the demand for cement, driven by societal needs be met:

- How can current resources meet the projected increasing demand?
- How can the associated environmental impact (CO_2 emissions) be mitigated?

Today, as the major part of CO_2 emissions from cement plants are generated from clinker production, the most effective strategy to reduce CO_2 emissions from cement production lies in reducing its clinker content. Reducing the clinker to cement ratio delivers 2.9 Gt CO_2 or 37% of the cumulative CO_2 emissions savings by 2050 globally in the 2DS compared to the Reference Technology Scenario (RTS). This is equivalent to 128% of current direct CO_2 emissions of global cement production, which highlights the level of ambition. Blast furnace slag fly ashes from coal-fired power plants, limestone or other raw materials such as natural pozzolans and calcined clay can be used to replace part of the clinker.

The opportunity of using calcined clay as clinker substitutes is one of the most promising avenues.

Calcined clay has been used in cement production for a long time (bridge construction applications were reported as early as 1932 in San Francisco), with Brazil systematically producing about 2 million tons (Mt) calcined clay per year since the 1970s (UNEP, 2016). Early compressive strength of cement decreases with greater portions of calcined clay used due to the slower reaction kinetics of this cement constituent compared to clinker (ECRA and CSI,

[1] IEA & CSI, 2018, Technology Roadmap – low carbon transition in the cement industry
[2] IEA, 2017, Energy Technology Perspectives https://www.iea.org/etp2017/
[3] McKinsey & company, 2018, Decarbonization of industrial sectors: the next frontier

2017). However, recent developments benefit from optimised combinations of calcined clay and ground limestone as cement constituents, potentially enabling up to 50% clinker displacement without affecting cement properties (UNEP, 2016).

In the quest of mitigating the environmental impact (CO_2 emissions) of cement production, while fulfilling the growing demand for cement and concrete, particularly in fast developing countries, several cement companies, government-owned as well as private, in various developing economies in Asia, Latin America and Africa are searching for alternative options.

A large country like India is the 2nd largest producer of cement (after China), accounting for around 8% of the country's industrial CO_2 emissions and the country's cement consumption is expected to grow between 6-10% annually. In the Paris Agreement, India has committed to reducing the emission intensity of its GDP by 33-35% until 2030 from the 2005 level.

In a smaller country like Cuba, there is a clear need to increase the domestic capacity of cement production, particularly at a time when the country has engaged in massive investment in construction (development of the country as well as touristic resorts). At the same time the Government of Cuba is exploring low emission cement technology for social housing and other infrastructure activities.

This global context prepared an appropriate background for the Swiss Agency for Development and Cooperation (SDC) through its Global Programme Climate Change and Environment (GPCCE) to support the Low Carbon Cement (LCC) Project, initiated as a Research and Development (R&D) project between the École Polytechnique Fédérale de Lausanne (EPFL) and the Universidad Central de Las Villas (UCLV) in Cuba. The overall aim of the project was to propose a new type of blended cement (with limestone and calcined clay), and demonstrate it is a reliable, viable and green cement through research, production and application. Its inclusion in existing or future cement standards is also needed to enable its future commercial production.
The LCC project contributes to SDC's overall goal of promoting sustainable development by mitigating the global risk of climate change. It is anchored well within the Strategic Framework of GPCCE by developing a solution for mitigating CO_2 emissions in one of the fastest growing sectors in developing countries and emerging economies. It thus contributes both to safeguarding development achievements from negative climate impacts and to a climate-compatible development trajectory. In addition, it contributes to reducing poverty by strengthening social housing potential at a lower cost and reduced environmental impact.

The Opening Phase of the LCC project was originally started (from January 2013 to March 2013) as an SDC-funded R&D project between the École Polytechnique Fédérale de Lausanne (EPFL) and the Universidad central de las Villas (UCLV) in Cuba.

Phase 1 of the LCC project (from June 2014 to May 2017) was subsequently conceptualized to transfer the know-how and experience gained in the opening phase, particularly in Cuba to a country with massive cement production capacity and demand: India was then selected.
Phase 1 focused on extensive research and testing with various blends of calcined clays, limestone and clinker. The new cement type was named LC3, standing for Limestone Calcined Clay Cement. The overall management of the project for Phase 1 was centralized at Ecole Polytechnique Fédérale de Lausanne (EPFL) but in order to conduct the research activities in India, EPFL established formal collaborations with 3 Indian Institutes for Technology (IITs) in Delhi, Mumbai and Chennai, building on their existing partnerships. EPFL also collaborated with Technology and Action for Rural Advancement (TARA), an organisation known for its applied research with extensive knowledge of the building sector.
IITs were involved in conducting scientific tests on raw materials used for producing LC3, as well as on the properties of LC3 and on its usability in different building materials like concrete. TARA's role was to map the source materials and coordinate production of LC3 on the

premises of small cement producers and support it in building demonstration structures at its field site.
In Cuba, EPFL continued its collaboration with UCLV in mainstreaming LC3 in Cuba.
Research carried out during Phase 1 found that a combination of calcined clay and limestone allowed reducing the cement's clinker content while maintaining a good technical performance. The main strategy was to develop and document scientific evidence by analysing, producing and testing LC3 in order to be able to persuade and inform the cement industry about this new technology and eventually incorporate LC3 into regulations on cement (i.e. standards).
As part of the project management cycle, SDC supported to conduct the review of the LCC Phase 1 in December 2016. To summarise that review report, it recommended that in Phase 2, the project would move from research to application, expand the base of the industry partners beyond cement companies and expand the geographical focus in a step-by-step approach. The project should coordinate with on-going global low carbon and sustainability initiatives as this can potentially increase the regional and global outreach.

The on-going Phase 2 (from June 2017 to May 2020) of the LCC project focuses on research, action and policy, gradually shifting from research, development and tests towards production and application of LC3, in partnership with cement companies and beyond while putting the necessary regulatory framework in place. The project strategy thus considered important not only to target the cement industry, but also to reach out to users (such as construction companies and architects) to make them aware of the merits of LC3 as a sustainable building material. Furthermore, the project aims to leverage the support for LC3 technology of policymakers engaged in the topic of climate change and convince them of its enormous potential of reducing the CO_2 emissions. Geographically, Phase 2 of the project continues to be engaged in India and Cuba and expand strategically to other emerging markets where growth of cement consumption is high and where there is a large unmet demand in housing and infrastructure. In order to engage with selected international partners and deliver targeted interventions, the establishment of regional Technical Resource Centres (TRCs) were envisaged in India and Cuba.

The key outcomes of Phase 2 of the LCC project have been planned as:

- The technical, economic and environmental viability of LC3 is scientifically investigated and validated.
- LC3 is produced by pioneering cement companies and showcased in representative construction projects in India, Cuba and other selected countries.
- A conducive regulatory environment is created for upscaling the production and application of LC3 through standards, policies and certification.

Total SDC outlay earmarked for the project is CHF 7.092 million (CHF 4.092 million already used in Phase 1 and CHF 3 million for the on-going Phase 2).
The financial contribution was used to support the underpinning technical studies in academic institutions, as well as for production and application of LC3. The main research activities focus not only on specific thematic areas of cement research (such as hydrate assemblages, pore structure, rheology, reactivity, durability and mechanical properties) but also on production and its application, environmental sustainability and cost effectiveness of the LC3 cement. The SDC support was complemented by industrial partners and a few cement companies who contributed time of their staff, raw materials testing, trial production of LC3 and further research support.
SDC also provides additional support to strengthen the project's outreach to the private sector through global networking and wide-scale awareness of LC3 technology. On that purpose, Swiss consulting company, Cementis GmbH, was contracted through a tender by invitation. The work carried out by Cementis supports the project activities of EPFL and other partners. The goal of Cementis' support is to accelerate the uptake of LC3 and to establish it as mainstream cement by facilitating the process of standardisation, acceptance by the cement industry for manufacturing it and supporting its widespread applications.

Cementis analysed the economic viability of LC3 production and its country attractiveness, delivering associated reports that were instrumental in enhancing the impact of the LCC project, and organized various outreach events (e.g. LC3 information days).

The LCC project's Phase 2, which is now reaching towards the end of the second year, is at a crucial juncture. Therefore, SDC has commissioned an independent review to assess the activities achieved in the project and to evaluate its impacts with regards to the project's objectives. The review was meant to highlight on what still needs to be done till the end of this phase. The review also looked beyond Phase 2 and provides some recommendations for a new Phase 3 to be developed, subsequently to Phase 2. The review also suggests a suitable approach for this Phase 3 and provides recommendations on how the cement sector may have to be reached out in a more holistic approach.

4. Objective of the review

The main purpose of the Phase 2 mid-Term independent review is to assess and evaluate the project results and achievements, to draw lessons that can improve the sustainability of the project benefits and to recommend future course of action.
The review is also meant to provide an independent critical view on how the SDC funded LCC project is being run, managed and implemented and to identify opportunities and scope for improving the strategy and direction of the project for the remaining duration of the on-going Phase-2 and beyond.
The review assessed the overall performance of the project, including appraising the project activities and their contribution to match the project objectives, by looking at key dimensions and criteria, as prescribed by the Organization for Economic Co-operation and Development (OECD) viz. relevance, effectiveness, efficiency, impact and sustainability.

Further details are described in the Terms of Reference of June 2019 and given as illustration in Annex 2.

The review is also meant to offer recommendations that could help consolidate the project achievements as well as ideas on follow-up activities to support the establishment of LC3 for industrial production. Apart from improving learning, the perspectives gathered through the review should help in effective design, planning, implementation and review of climate change and mitigation policies and actions in future, not only in India but also in other countries with a significant potential for reducing CO_2 emissions from the cement sector.

5. Methodology and Approach

a. Review Team

This review was conducted by two independent consultants: Philippe Fonta (Team Leader), founder and CEO of SCRUM-Consult and Bernard Mathieu, founder and consultant at HOP^3 Consulting, from July 15 to end of October 2019. Andrin Fink from SDC completed the team and Atul Khosla (Independent consultant in India) supported the team during the review consultation trip to India from August 5 to August 9, 2019.
This core mission team received specific technical input and support from selected international and national experts upon requirements.

b. Overall approach

The Phase 2 Mid-term review conducted by the review team was divided into 4 major blocks:

(1) Desk Study:

The review team engaged in a detailed Desk Review by carefully studying all the available documents of Phase 2 (as provided by SDC) including the project document, project log-frame, outcome monitoring summaries, six monthly and annual operational and financial reports, agenda, minutes/ proceedings of the steering committees and advisory board meetings, agenda and proceedings of workshops held at various levels, documentation related to the project including back to office note, minutes of meetings held in connection with the project etc.

A list of documents provided by SDC is given in Annex 3

The review team also went through various knowledge products generated out of the project initiative, including newsletters, tools, methods and methodologies, media coverage/ reviews, books, roadmaps etc…

(2) Interviews with key stakeholders:

The review team had detailed interactions with project partners, industry stakeholders, relevant government agencies, industry associations, etc. Face to face meetings when possible or phone/video conferences have been set up and gathered information has been used to answer the key questions that the review is mandated to address. A list of people and organisations with whom the review team interacted is given in Annex 4

A debriefing session was organised through a conference call with SDC (including Programme Office in New Delhi) on September 23rd in order to present and discuss interim findings.

A complete feedback of the conclusions and recommendations of the review team happened on October 17th and the present report was finally delivered on November 1st, 2019 to SDC, in order to serve as basis for their decision-making process with regards to the next steps

(3) Interactions with project partners in Cuba, India and beyond:

The review team managed to obtain ground realities for selected countries in India, Cuba and Guatemala. Enhancing this interaction to Africa (Egypt or Ivory Coast) was not appropriate at this time, being premature, although discussions about the Ivory Coast case were conducted with some of the involved stakeholders.

They had detailed discussions/ interactions with stakeholders at different levels (at National as well as Sub-National), including with the project implementation agency and cement industry/companies. In doing so, the review team broke into two groups to cover the different continents; Bernard Mathieu went to India, supported by Atul Khosla, whereas Philippe Fonta and Andrin Fink (SDC) visited project activities in Cuba and Guatemala (visit of the La Pedrera plant where Cementos Progreso made some trials to produce LC3 in a dryer, and to visit their R&D Center (located at the same place)). Philippe continued his trip by participating to the annual technical congress of FICEM (the InterAmerican Cement Federation), held in Punta Cana, where he conducted additional discussions with stakeholders from Guatemala, Peru, Colombia Mexico, Dominican Republic and the US, to name a few.

- The organization of the Indian trip visits was set up by Anand Shukla (SDC India) in cooperation with Bernard Mathieu and Atul Khosla, who joined the visits and participated in the interviews.
- The organization of the Cuban trip and visits was set up by Fernando Martirena (CIDEM) in cooperation with Philippe Fonta and Andrin Fink, who joined the visits and participated in the interviews.
- The organization of the trip and visits in Guatemala was set up by the team from Cements Progreso in cooperation with Philippe Fonta and Andrin Fink, who joined the visits and participated in the interviews

An agenda of the activities conducted during for these two trips are provided in Annex 5 for India and Annex 6 for Cuba and Annex 7 for Guatemala and Punta Cana respectively.

(4) Debriefing of SDC staff and preparation of final Review Report:

Following the different interviews, the on-site meetings and the specific debriefs by the team members, a final Review report was drafted and provided to SDC for comments on October 14th.
A presentation was given to SDC in Bern on October 17th in order to answer some questions and provide clarifications on the report if needed.
Following that meeting, some adjustments have been integrated in the report before the final document was delivered to SDC by the Review Team, as per the agreed revised scheduled plan, on November 1st, 2019.

6. State of preparation and time schedule

a. State of preparation

The Review Team had email exchange between the different members and SDC together with side meetings between the different members before the kick-off meeting on July 8 as a virtual on-line meeting.
The kick-off meeting was mainly devoted to

- ensure that the objectives of the review (an independent assessment of the projects, its achievements with regards to the initial objectives and the recommendations for the rest of Phase 2 and beyond) were perfectly understood by the Review Team;
- discuss the planning of the project including the people interviewed and the planned on-site visits; and
- to clarify any questions the Review Team could have.

As a result of that meeting, a review schedule was agreed. However, this planning was updated as the project evolved, to consider the availability of all stakeholders, the potential need to come back to some stakeholders after subsequent interviews. The updates of the review schedule were all agreed with SDC as being compatible with their own timing in the view of their internal discussions and decision-making processes. The final schedule is provided here below, in paragraph 6b.

b. Time schedule

The review is expected to adhere to the following timeline as far as possible, a copy of which was discussed during the kick-off (on-line) meeting on July 8th, 2019 and subsequently updated:

S. No.	Review Steps	Proposed Timeline (2019)	**Action : PF (P. Fonta) – BM (B. Mathieu) AF (A Fink) – Bold=leader for the task**
1	Kick-off meeting/ briefing at SDC Bern/ India	8th July – 10 AM	On-line conversation
2	Desk Review	15th – 25th July	Full set of documentation given by SDC to PHF, BM and AF
3	Conduct strategic interviews (meeting and phone calls)	15th – 25th July	Cf. Annex 4
4	Submission of the Inception Report (document to be sent)	1st August	**PF/**BM/AF
5	Meetings with Relevant stakeholders in India[4]	05th August – 09th August	**BM**/Local representative (5 days)
6	First Debriefing – Delhi	Last day of BM's trip in India	**BM** face to face mtg in SDC India office PHF to join by phone/video call
7	Meetings with Relevant stakeholders (+ visits) in Cuba / Guatemala?	26th August – 30th August	**PF**/AF
8	Meetings with Relevant stakeholders during FICEM events (Dominican Republic)	1st September – 6th September	**PF** – Invitation confirmed by FICEM
9	Debriefing /video conference	13th September	**AF** to provide phone platform PPT slide presentation
10	LC3 workshop in Peru	24th September	**PF attended** online and contributed to some panels on the phone
11	Submission of the draft report	14th October	**PF**/BM/AF (no meeting)
12	Response / feedback on the draft report – **meeting with SDC** - Presentation	17th October	**PF**/BM/AF Meeting in Bern (SDC) and conference call with India
13	Submission of the Final Report	5th November 2019	**PF**/BM/AF (no meeting)

[4] Mr. Atul Khosla (Independent consultant) joined the team for the interviews in India (August 5th – August 9th)

7. Evaluation and assessment of first half of LCC phase 2

According to the Terms of Reference, the review was based on the OECD-DAC Criteria regarding Relevance, Effectiveness, Efficiency, Impact and Sustainability. The specific elements to consider for the evaluation, associated to these criteria, are given in Annex 2 for illustration

a. Relevance

The relevance of the LCC project is assessed as "very high".

LC3 offers a credible pathway to deliver a substantial mitigation of CO_2 emissions in the global cement sector (offering a sustainable opportunity to reduce the clinker/cement ratio) and to preserve limestone reserves. In addition, its demonstrated performance (though lab tests and real-life pilot production and applications) makes of LC3 a real solution to replace traditional Portland Cement and to complement existing blended cements on the market.

This relevance was notably recognized at global level in the IEA-CSI "Technology Roadmap – Low Carbon Transition in the Cement Industry" (released in 2018)[5], where calcined clay is referenced as the most promising clinker substitute within upcoming decades and as one of the crucial levers of the sector to achieve CO_2 mitigation targets in line with the Paris Agreement. The roadmap indicates that "Cements based on calcined clay and ground limestone are considered to penetrate the market in the 2-degree scenario (2DS), reaching 27% of the global cement production by 2050".

This is all the truer as "The global reserves of raw clay are considered effectively unlimited" (or – more realistically – vastly available) while "other clinker substituents, such as slag and fly ash, are envisioned to be significantly less available in the 2DS". So at least for a certain time, even if the demand for clay would drastically increase, the impact on the clay's price could be considered as negligible so far. In recent prospective presentations made by some knowledgeable institutes (including On-field Investment Research during the recent FICEM Technical Congress in Punta Cana), the anticipated decline in worldwide availability of slag and fly ash as clinker substitutes makes of LC3 a key alternative solution.
Indeed, mainly for environmental reasons (climate change mitigation and better waste management),

- the energy production from coal is targeted by policymakers and it is very likely that the quantity and quality of available fly ash will decline in the future;
- the availability of slag (as a waste product from steel manufacture) will also decline as all sectors will have to reduce the waste of their operations, and an increasing part of steel derives from electric processes.

Therefore, LC3 appears as an additional clinker substitution option and not as a competition to slag and fly ash. The same type of conclusion could be drawn with regards to the usage of pozzolan as substitution cementitious materials. For the time being, in some countries where long-standing volcanic activity has largely influenced the geological structure (for instance some parts of Peru, Guatemala), the huge availability of pozzolan drove the cement producers installed in these regions to consider pozzolan as a long-term potential for clinker substitution. This can make them probably less sensitive to the work already undertaken on LC3. However, in Guatemala, where pozzolan is abundant, the perspective adopted by some cement manufacturers is different in the sense that they simply consider LC3 as another type of cement

[5] https://webstore.iea.org/technology-roadmap-low-carbon-transition-in-the-cement-industry

to be put on the market, offering higher clinker substitution rates for equivalent of better performance.
In some regions, notably in India, the use of clay represents an attractive solution to a growing scarcity of cement grade limestone, while the demand for cement and concrete keeps increasing.

The major emission mitigation potential of an industrial scale deployment of LC3 and the established technical viability of this option demonstrate the important contribution of the project to the SDC Global Programme Climate Change and Environment Strategic Framework and notably to its components nr 2 (Low-emission development) and nr 3 (climate-resilient development and sustainable natural resource management) . This last element has been particularly identified in Cuba where the availability of resources (limestone for clinker production, but also slag and fly ash) are limited and certainly a real challenge in a country where development of affordable housing and infrastructure is essential for the country and its government. Moreover, with the difficult conditions resulting from a recent shift in the US policy towards Cuba (with new embargo decisions) and their potential influence on neighbouring countries, the availability of clay in the county is clearly perceived as an essential vector for the overall development of the country.

On a more global perimeter, the project also contributes to the transversal component (Climate Change and Environment in Development Cooperation), mainly in its Development Cooperation component as identified in Cuba and elsewhere. In this context, the project can potentially become a huge contributor to helping countries reducing their overall CO_2 impact and supports for possible more ambitious Nationally Determined Contributions (NDCs) in their regular updates. In addition, the project can also more widely contribute to the United Nations Sustainable Development Goals (SDGs) through enhancing opportunities for affordable housing and resilient infrastructure.

The strong interest shown today by smaller cement players for LC3 as well as the growing interest of major international cement producers are clear proof of the very high relevance of the project for the cement sector. As expressed by many stakeholders during the interviews led by the project review team with a large number of cement companies and (global or national) cement associations, the LC3 option is today considered as realistic, reliable and viable as a result of the scientific body of evidence generated by the project.

It will be very important that the project further raises awareness and communicates on the composition and performance of the product during the next months in order to increase the interest of more cement manufacturers and to mobilize policymakers, standardisation bodies and construction experts and influencers (builders, architects, developers). Today it seems that some people still consider this product as being less robust than other blended cement because of the bad (weak) reputation of clay (event blended, after calcination with clinker). It will also be important to develop very basic messages towards final consumers or users, typically the people living in houses or using infrastructure built with LC3 so that the acceptability of clay (calcined and combined with limestone and clinker) is higher. Indeed, by adding limestone to this blend, the robustness of the LC3 product is even better than traditional OPC, but this information and the results of the test performed by the universities and TRCs in India and Cuba deserve further diffusion.

The cement industry and the overall construction sector being (in some respects) conservative, the involvement of major cement players will be instrumental in the development of the project at higher scale. Indeed, when they will publicly move towards a higher consideration of LC3 in their strategic positioning and portfolio, they will immediately enhance the interest of other cement manufacturers to follow.

At global level, some major international cement companies confirmed that LC3 makes indeed full part of their innovation agenda now, driven by the recent increase of CO_2 prices in the EU

Emission Trading Scheme (for European plants), and other possible economic measures in other parts of the world, by the foreseeable scarcity of other clinker substitutes (resulting in increasing market prices), their raw material strategy and/or cost reduction purposes. Actual investment projects are under development before submission for approval within several companies. It should be noted that LC3 should be considered as a new option and a new product, joining the portfolio of solutions developed by cement manufacturers to reduce their CO_2 emissions and subsequent impact on climate change while enabling the increasing demand for cement and concrete to be met by enlarging the number and quantity of available resources (extending for instance the lifetime of limestone quarry operations).

LC3 should not be presented as the unique solution for CO_2 mitigation in the cement industry, replacing the currently cost-intensive carbon capture and utilisation or storage (CCUS) options. Such statement does not act as a support for the strong development of the product, particularly for companies who already invested a lot in CCUS technologies. The challenge for the cement sector to meet its objectives associated with a 2DS are so huge that all solutions much be looked at together: LC3 recently emerged as one of these solutions, thanks to the LCC project and its teams (and the support of SDC) and it must now be enhanced in terms of awareness and capacity to scale up worldwide.

The energy, credibility and passion of the LCC project team and more specifically of Pr K. Scrivener were recurrently mentioned as crucial success factors of the project over past few years. The partnerships established with Technical Resource Centres in India and Cuba have demonstrated to be efficient to develop collective knowledge on the project.

<u>Elements specific to India</u>

In India, it is worth noting that beyond the need to develop affordable housing supported by financial and fiscal measures, the government has requested the adoption of cement instead of bitumen for the construction of new road projects as cement is more durable and cheaper to maintain in the long run.

These measures contribute to supporting a strong current and future demand for cement production, for which the issue of resource management is very high on the agenda due to the limited proven reserves of cement grade limestone.

In addition, the ambitious NDCs set up by the government of India, in particular with the focus on developing renewable energy sources, may limit the availability of fly ash to partially substitute clinker in the long-term (not immediately as coal is still one of the main sources to produce energy in India). However, clinker substitution is essential to support the increased demand for cement and concrete as indicated above and at the same time reduce the associated CO_2 emissions. It will be essential to demonstrate the impact that LC3 can play in the achievement of the country's objectives as expressed in the NDCs and to accelerate the development of the associated standard in the country. Additional players such as the Cement Manufacturing association (CMA), the National Council for Cement and Building Materials (NCB) and The Energy and Resources Institute (TERI) shall be considered as potential partners and influencers in the next steps of the project.

The awareness level of the potential and technical features of LC3/LCC cements may be considered as high among cement players and key stakeholders (standardisation bodies, some relevant public authorities), even if some more work has still to be delivered to provide reassurance on specific technical issues (mainly concrete durability and tailored concrete admixtures), to support standardisation and secure active support from relevant Ministries to market deployment. These remaining concerns represent the major challenges to be overcome within the next period (see chapter related to recommendations for future work).

Elements specific to Cuba

In Cuba, the specific situation of the country and the embargo conditions make of the LCC/LC3 cement an opportunity for further developing the country by building affordable and resilient infrastructure and homes, while extending the availability of limestone resources. Strongly supported by the governmental bodies, the project is soon entering in its production phase and cooperation with neighbouring countries is also a clear opportunity.

It is worth mentioning that the government bodies are well aware of the existence of the LCC/LC3 project and are ready to support it. However, the interest they have in the product is mainly driven by its social and economic potential, enabling affordable housing and infrastructure, providing resilient product, particularly in coastal areas. Durability tests have convinced several construction companies to consider building bridges and hotel resorts in coastal areas. Main advantage for them is LC3's contribution to reduce corrosion of concrete in a marine environment. Considering the given geographical conditions and the exposure to marine environment, LC3 has the advantage of reducing the risks of corrosion of reinforced steel. This advantage has been scientifically proven in the lab as well as in specific exposure sites along the sea. This advantage of LC3 should be further evaluated as it gives an additional strong argument for LC3 applications in many other countries of Latin America (and beyond) especially on islands and construction activities along the coastlines. With climate change, the development of severe weather events (hurricanes, stronger sea waves, …) and more regular changes (sea level increase), construction using LC3 could also represent an additional argument for resilience in buildings and infrastructure in regions prone to this type of events.

Other cement companies in Latin America have called upon the Cuban experience (CIDEM) on contract basis to better understand the advantage and to explore replication in their own countries.

Elements specific to other countries

Other countries than India and Cuba do not have the chance and opportunity to have a local or national Technical Research Center (TRC) associated to the development of LC3 product. However, the LCC team and the TRCs have conducted a series of Information Days and some side event presentations in major international Forums, like the Conference of the Parties (COPs) of the United Nations Framework Convention on Climate Change(UNFCCC) to open the results of their tests and development to a wider audience worldwide. Through these events, some stakeholders in different countries heard about LC3 and showed interest for it.
It will be important, in the future, to identify where the involvement of the project team can provide the highest potential of awareness raising, capacity building and LC3 deployment, while at the same time having a stricter management of the travel expenses involved. For instance, as the involvement of machinery and additives manufacturers will be essential in the future, the presence through presentations and side-contacts with these stakeholders might be privileged, other main international political forums such as UNFCCC COPs. Conferences organised by national and regional cement associations (CEMBUREAU, FICEM, PCA, CMA, …) seem to be the targeted events together with various conferences organised by cement and concrete specialized magazines (for which the machine and chemical manufacturers are the main sponsors of the events and attend with numerous people from strategy to technical environments.

Running the risk of the elaborating an exaggerated statement, a clear tendency has been observed:

- The big manufacturers that heard about LC3 and identified a potential opportunity as a new type of product initiated some internal research.
    - This process is quite recent, so LC is not yet part of their global strategy (even if it is considered at the moment in some of them)

    - Their size, market volume and strong dominant position in some markets means that they do not feel the need to getting support from Universities or existing TRC, considering that they have the on-board resources to carry-on some tests
        - In the best case, they will lose time and get comparable results
        - In the worst case, they will not evaluate the optimum solutions, too much focused on traditional cement manufacturing techniques and not considering information from outside the cement sector (like the sector of ceramics and tiles), thus getting less potential for the LC3

- The smaller manufacturers seem more open to collaboration with existing TRCs, in order to benefit from the achieved work and not start the test from scratch again, for which their financial capabilities are reduced. This is the case in Guatemala and Peru for instance, but the same diagnostic is likely to be drawn on other countries in Latin America, Africa and South East Asia.

b. Effectiveness

The effectiveness of the LCC project is assessed as "high".

Overall, the review team concludes that the project is well on track towards the overall project goal for phase 2, which is to establish LC3 as a reliable, viable and green cement. The LCC project generated a strong body of scientific and technical evidence which forms a strong foundation for future industrial deployment of LC3. Initial production (so far limited) and tests performed (India, Cuba, Guatemala, Peru) have confirmed the tests done in the labs and demonstrated positive results for multiple applications (as seen during the visits in the various countries by the Review Team).

Phase 2 / Outcome 1 (Research): "the technical, economic and ecological viability of LC3 is scientifically investigated and validated"

This expected outcome may be considered as well on track, thanks to the combined work of EPFL project team and its partners (notably Cementis at global level and national partners in target countries) as well as the team at UCLV in Cuba. For instance, the UCLV team is a gender-balanced team composed of technical and economic experts as well as PHD students; they developed some analyses specifically focused to the Cuban conditions and demonstrated comparable results to the ones demonstrated by Cementis on a global scope, for instance on the economics and financial needs for LC3 development. There were a few remaining concerns expressed by stakeholders, notably on early strength, long term durability and on use of admixtures. These should still be further addressed by the end of Phase 2, either by limited additional research or by efficient communication of existing evidence.

Phase 2 / Outcome 2 (Action): "LC3 is produced by pioneering cement companies and showcased in representative construction projects in India, Cuba and selected other countries"

Pilot production trials were indeed conducted by several cement companies over the past few years. Large scale industrial deployment still requires overcoming several barriers (notably/essentially related to standards and norms). These hurdles essentially explain why few representative construction projects actually took place. There are however some promising industrial projects that should deliver regular production of LC3 in the coming months:

- Cuba: in a collaboration between CIDEM and the company IPIAC SA[6], a pilot plant for the calcination and grinding of LC3 has been designed and installed in Cuba at the UCLV site. Part of the CAPEX investment for this plan was done by UCLV and part as investment from IPIAC (about 50/50). The plant consists of a rotary kiln with a capacity of calcining up to 100kg/h of clay and a 250kg/h grinding system with pneumatic extraction. The operation of the unit is fully automatic and most of the processes are sensor- controlled, thus information such as residence time, calcination temperature vs reactivity, particle size and others are continuously measured and streamed through the internet, producing the needed feedback for the operation of the equipment. The plant is supposed to start production in early December, following the final validation of the production test carried out last week (October 21-25).
  It is worth noting that the first experimental trials carried out in Cuba so far have been done by Geominera del Centro where the production capacity is about 6 tons per day.

- Guatemala: the leading cement manufacturer (Cementos Progreso) was made aware of the existence of LC3 by attending one of the Information Days carried out by the project team under the leadership of EPFL. Renowned as being a proactive, innovative

[6] IPIAC is a company with a huge experience in clay industry (bricks, roof tiles, ceramics), now embarking on the cement business with LC3 product. They indicated that an opportunity of about 30 projects emerged since they initiated the discussions for he Ivory Coast project

company, they became interested in the project, considering LC3 as a potential new product to be put on the market ultimately as an additional solution in their portfolio of products. They connected with the Cuban TRC to get more information and decided to launch some trials. In November 2018, they manufactured more than 100 tons of LC3, assisted by CIDEM.

- The calcination of kaolinitic clay was carried out in a rotary drier at temperatures around 700-900° C. LC3 was inter ground in an industrial ball mill.
- Then, the material was used for several applications with excellent results :
  - Concrete: LC3 compressive strength overtakes concrete made with a structural cement with 90% clinker content after 3 days
  - Dry mortar and concrete: the material was used to make dry mix
  - Masonry mortar: LC3 used for a wall of concrete blocks

It is worth noting that the clay used in these tests was having about 66.9% of kaolinitic content, which is probably a bit high for this type of application, thus requesting a higher volume of additives (traditional additives to cement and concrete such as plasticizers). A different type of clay (obtained through an optimized screening and geological search process), calcined in an adapted calciner (a drier is definitely not optimum), combined with separate grinding for the different products before mixing should reduce the need for higher additive volumes and should provide additional short-term strengths to be able to have comparable (even better) performance than traditional OPC with reduced environmental impact and limited clinker factor (50%).

The Review Team organised an informal discussion between representatives of Cementos Progreso and Fernando Martirena (CIDEM) to exchange views about the current challenge of short-term (below 3 days) strength issues of LC3 applications and general consensus was achieved that the current results were probably due to a sub-optimal process and resource material.

Cementos Progreso confirmed that they signed a new contract with the Cuban TRC in order to support them in the next phase when they want to product LC3 at industrial level, possibly using a clinker kiln that they are stopping in one of their existing plants instead of the drier to calcine the clay. Although the process will not as optimal as building a specific kiln (comparable as the one built with IPIAC in Cuba), it could be a good compromise together with a limited CAPEX expenditure. The production should start in the coming months and certainly before the end of Phase 2

- Colombia: Cementos Argos indicated interest in LC3. They initially got into discussion with the TRC in Cuba but then, for various potential reasons (size of the company, US shareholders, …) they decided to pursue on their own and stopped cooperation with Cuba to engage discussions with Brazil, a country which has huge experience in calcined clays, but not necessarily with LC3 opportunities (no combination with limestone). In addition, the clays available in Colombia are different from the ones in Brazil.
  They are currently establishing a huge LCC plant in their existing Rio Claro site, using a long clinker kiln to be adapted for production, combined with a flash calciner equipment, together with a rotary cooler. As indicated above, adapting an existing clinker line to produce calcined clay is fully possible but is not the optimum and adapting a huge plant like Rio Claro (capacity of 1500 tons a day) has a CAPEX cost of about 70 Million of dollars. Presenting this figure (specific to the case of Argos plant) can be considered as a financial burden for some companies that would be interested in engaging on LC3 production evaluation. It will be worth mentioning other cases for which the CAPEX cost is much lower.
  Argos indicated that the production should start before the end of 2019, which means that some first insights could be seen before the end of phase 2. They also indicated that the standard in Colombia (based on performance of cement) allows them to have different compositions, if the performance of the final product is guaranteed. For them,

LC3 has a good potential as one can control the quality of the clay and the calcination process, whereas the quality of fly ash is quite variable depending on the source. Moreover, they are quite familiar with pozzolan management, and have engaged a PHD expert (from Madrid University) to support them in this exercise. Although they have not yet engaged with Colombian governmental authorities, they think that the CO_2 reduction potential will be an element of high interest for them and they plan to engage with them soon. In addition, due to their market coverage they see potential for duplicating the exercise of Colombia to other countries in Central America and in the US, but no precise timing was given to the review team. We consequently expect that limited advancement will be available at the end of Phase 2.

- Ivory Coast: A huge specific LC3 plant is being built by IPIAC, for a cement manufacturing company established in Turkey and having operations in Ivory Coast. As this plant is specifically designed to produce LC3 cement, it should be the very first plant delivering with LC3 cement with optimized production process and should serve as a reference and model for future other productions. The delivery of all the equipment of the plant are scheduled for January 2020 and after a period of assembling and final check, the LC3 production is expected to start in June 2020. It will be unfortunately too late with regards to the schedule of LCC project's Phase 2 to benefit from the outcome and the results of this plant's production. It is worth noting however that this plant will be the biggest plant in operation at that time, with a capacity of 250.000 tons/year of calcined clay, leading to an overall production of 750-800.000 tons of LC3 per year.
  Clearly, the experience that will be gained from this plant operation (including the challenges and the solutions to overcome them) will have to be shared with the other plants starting operations. Indeed, the production is expected to start at the beginning of the future Phase 3 of the LCC project, and that phase should build on that project and equivalent subsequent ones to pave the way for the LC3 cement to sustainably enter the market.
  On a financial point of view, the equipment for the full clay calcination line represents around 12-13 Million € and the total investment of all the plant with clinker milling unit is around 38 M€. This is far lower than the CAPEX needed for a typical cement plant and provides an additional opportunity for cement manufacturers to embark on LC3 production, particularly if demand for cement and concrete is increasing in the countries where they operate. This lower CAPEX enables also a good return on investment (this was confirmed in most of the selection of machinery by the economic analysis done by CEMENTIS and for which the calculations done at UCLV concur with the same results).
  The adoption of LC3 will reduce the environmental impact, extend the availability resources of exiting materials (such as limestone) and require lower capital investment than a traditional approach of creating an additional clinker line.

It is worth noting that IPIAC SA is a company that builds Ceramics and related Machinery with the customers specs, composed of own companies established in Spain, Portugal, Brazil and Italy entirely devoted to the sector of structural ceramic industry: bricks, roof-tiles, floor-tiles, coves, etc. Coming from outside the cement sector, they have the advantage of bringing their knowledge and expertise on the management of calcined clays to the cement sector with a new eye, and from an external perspective without any pre-conceived ideas from inside the cement sector. This opportunity can guarantee an optimized introduction of calcined clay (type, process, machinery, additives…) through the LCC project.
Finally, major international cement producers indicated their willingness to invest in calcined clay cement production in several countries over next few years, notably in Europe and Africa. Investment projects are being drafted for internal approval.

Phase 2 / Outcome 3 (Policy): "a conductive regulatory environment is created for upscaling the production and application of LC3 through standards, certification and policies"

This outcome has not been fully achieved and will still require some additional years of efforts. The project team and its partners delivered their best efforts to support standardisation processes in various regions. The inherent complexity and slowness of these processes can of course not be imputed to the LCC project.

With regards to standards and norms, we can identify two types of countries:

- Countries where no standards exist to accommodate the use of LC3 cement in structural concrete applications: for instance there are currently no Indian Standards yet available covering LC3, which precludes their use in structural concrete applications and, hence, to meet the goal of a "mainstream cement". Currently the use of LC3 is restricted to the production of non-structural concrete elements, such as roof tiles, pavement blocks and non-bearing masonry blocks as well as to masonry mortars, which may taint the product as "second class"
    - It seems preferable to be a bit patient and get the appropriate standard elaborated (the stakeholders there think that it could last about 3 more years but that more rapid conclusion in one year could be envisaged) in order to avoid constraints on the applicability of LC3 cement.
    - Some additional research and innovation work and/or advocacy work is required to support this process (see below).
- Countries where standards exist for blended cements and where LC3 can be covered by these existing standards. For instance, In the Americas LC3 fulfils requirements through the standard ASTM C 595/C595M – 16 'Standard Specification for Blended Hydraulic Cements', which allows as low as 45 per cent clinker, plus the combination of up to 15 per cent limestone and up to 40 per cent pozzolan. European standards still do not allow clinker content below 65 per cent at present, but the introduction of a 50 per cent clinker class is in progress. With the increased interest of major EU-based cement manufacturers, one can expect that this standard will be developed and published sooner rather than later (2 to 3 years are expected).

In India, for instance, the set-up of a patent for LC3-type cement slowed down the process. Following extensive discussion with the patent-owning cement manufacturer, an agreement was reached, and the standardisation process could move ahead. Remaining efforts should be dedicated to bringing this process to a favourable end and to ensure government policy support to implementation. The ongoing standardisation process is expected to take an additional 1 to 3 years depending on 2 main factors:

- ***Additional reassurance*** should be provided both on durability concerns related to carbonation (accelerated tests on long term durability, defining specifications for low clinker cements in different environments) and on manufacturing requirements (quality control, manufacturing process) to ensure a sufficient quality of cement.
    i. The role of the National Council for Cement and Building Materials (NCB) seems to be crucial for a successful outcome.
    ii. The funding of additionally required tests still needs to be clarified (committed contribution from IFC to be complemented by funds from other parties).
- External pressure on organisations playing a role in the standardisation to complete the process within a reasonable timeframe. Some organisations like Cement Manufacturers Association (CMA), The Energy and Resources Institute (TERI) could support the process together with NCB. The importance and leadership of some involved companies like Dalmia could be instrumental, ensuring the right level of pressure for the desired standard type. Indeed, Dalmia has publicly committed to become carbon-neutral around 2040, so all available solutions need to be developed and used to their optimum potential,

LC3 production included. In addition, the role of Dalmia CEO in major leading positions at CMA and NCB at the moment could help the process.

The main challenge related to the ongoing standardisation is to avoid limitations in the use of LC3 as well as strict limitations on clinker substitution rate which would strongly reduce the incentive for companies to proceed to market deployment and considerably decrease the contribution of these cements as a solution to sustainability challenges (crucially, climate change). An excessive pressure to accelerate the process might result in tougher limitations related to the applicability of LC3 (confining them to precast products without reinforcement or masonry mortars).

Interviewed cement companies' representatives clearly stated that the LC3 option would undoubtedly not be so high on their innovation agenda without achieved project outcomes and the commitment of the project team and of its partners.

In India, the support provided by the established TRC is appreciated by cement companies at this stage of development. Additional research & innovation work might be carried out and achieved by Indian institutes and research centres, such as:

- Impact of raw materials quality (specifically on clays) on LC3 Cements in order to further increase clinker substitution,
- Development of tailored admixtures to achieve sufficient workability,
- Real scale demonstration projects to showcase the applicability of these new cements.

The role and support of Indian TRC should however be reconsidered towards a potential third phase in order to further facilitate industrial scale implementation and fully benefit from the capacities of the TRC, in combination with other partners:

- Technico-commercial approach: handholding cement producers in their shift towards LC3 cements (through identified service providers):
- Guidance on the sourcing of clay (mapping of clay resources, quality checks, impact on land surface…),
- Guidance on manufacturing and support to companies to build the business case (working with technology suppliers): revamping of plants to accommodate LC3 production, calcination process, figures on required investments, ….

The Review Team believes that the existence of the TRC can only be financially sustained if it develops the capacity to provide a holistic support to cement companies willing to transition to LC3, not only focusing on cement and concrete technology aspects but broadening its scope to all related aspects (creating a LC3 "ecosystem" of private companies in each of the relevant countries).

The dissemination approach promoted by the project and Cementis is overall considered as relevant and effective. It should however be further strengthened by active engagement with local/national stakeholders with established reputation in target countries (aiming at supporting cement companies with all required information for the development of investment projects) and notably with technology providers (material suppliers) and admixtures producers (see chapter related to recommendations for future work).

In most countries, it is essential that local / national stakeholders are involved and driving the overall process as recommendations coming from abroad might be considered as intrusive in the worst case or not customised to the internal specificities of the country in the best case.

As China is responsible for above 50% of the cement production worldwide, it might notably be interesting to consider the potential of LC3 for that country and having national stakeholders involved will be essential for that country, for which an absence of national experts involved would be a showstopper.

In order to support the efforts of individual companies and to overcome the traditional conservatism of the construction sector, awareness campaigns, conferences, trainings should be (further) organized. In India, the involvement of strong Indian partners (such as the Indian Concrete Institute, the Cement Manufacturing Association, the Associations of Structural Engineers or others) is highly recommended.

An advocacy program should be designed and implemented, initially targeting key Indian Ministries and official bodies (Ministries of Roads, Railways, Environment, Housing, Urban Development, Central Public Work Department, Bureau of Energy Efficiency) as well as the Prime Minister Office and/or Niti Aayog (Policy think tank of the Government of India). The programme should be built on a quantitative environmental and social impact assessment for LC3 with an explicit link to existing policy objectives of the Indian Government
For both the awareness and advocacy campaigns, exchanges of experience should take place at international level between companies having piloted the production and/or application of LC3 and companies inclined to learn from these experiences. Major international conferences and forums represent real opportunities to nurture these exchanges, and some webinar (more specific sessions) should also be considered.

c. Efficiency

The efficiency of the LCC project is assessed as "high".

Based on our numerous meetings and discussions with project's stakeholders (through interviews and visits), we can conclude that project resources have been used in an efficient manner and that required activities have been accomplished in a timely manner. During the project's Phase 2, it is obvious that the project moved from the status of lab and university tests to reach industrial sector and cement manufacturers, as well as other stakeholders like policymakers and standard-setting entities. This was one of the main objectives of the Phase 2 and it was accomplished. Of course, one would always like to have more advanced results, but Phase 2 of the LCC project is really a key milestone in the overall project and LC3 development, expanding from a test phase (for which the initial project leaders are comfortable to drive and lead the actions, as they mainly depend on their only involvement) towards an implementation phase with the involvement of additional stakeholders and of conditions and context that are beyond the mere traditional responsibilities of the projects leading team. We can say that the Phase 2 drove them outside of their traditional zone of comfort and they reacted professionally by involving additional stakeholders such as experts from the cement manufacturing and markets (like Cementis) and from the ceramics industry (like IPIAC). This "open" mindset will be more than ever important as partnerships will have to be established in order to scale up the development and implementation of LC3 as a mainstream product.

Indeed, the engagement with relevant stakeholders at global, national and local levels must be sustained and/or strengthened in order to help accelerate adoption of LC3 by market players and policymakers. The project review team concludes from its activities that the generated body of evidence and the existing level of awareness about LC3 are solid foundations for a foreseeable future industrial scale deployment. However, this deployment might be much slower than required to address the global climate urgency if efforts from a committed project team were to be suspended. It might even become a niche product, if the resources to develop the knowledge, properties and implementation process were not enhanced now.

The project team undertook series of action to try and secure the future of LCC project beyond Phase 2, with the final goal of establishing LC3 as a mainstream cement. For external reasons that created some unexpected barriers to implementation (Aalborg patent in India, embargo in Cuba reactivated with the new US administration…) and the need for the project team to involve some resources in overcoming these barriers (agreement in India about the initial patent and reactivation of the standard-setting process, creation of a Swiss-based company to avoid any direct link with a Cuba-based initiative…), it was not possible, so far, to ensure the full sustainability of the projects initiatives beyond the Phase 2, without having additional resources.

<u>Elements Specific to India</u>
The 5 Indian cement producers we met during our field trip of August 2019 underlined the excellent collaboration with project implementing agencies and Indian partners of the project;
Additional efforts should be dedicated to bringing the ongoing standardisation process (Bureau of Indian Standards) to a successful end, possibly through extended engagement with key local stakeholders;
Now that the "patent" issue is solved, room for acceleration of the standard-setting process exists.
In order to establish LC3 as a mainstream cement, efforts should also focus on engagement with technology providers, admixtures suppliers, concrete producers and on advocacy towards governmental bodies.

Elements Specific to Cuba

The development of LCC project has reached a very high level of implementation. However, the Cuban market is rather limited and the experience of the various stakeholders in Cuba is being used to widespread information and expertise in other neighbouring countries, when these countries are not involved in a political embargo with Cuba. In order to minimize the risk of preventing the Cuban TRC to intervene with other stakeholders only for political reasons and the fact that they are based in Cuba, a company was created with home base in Switzerland (Ecosolutions) as a commercial response to the growing need for channels to serve less developed countries with hardware and technology transfer. Ecosolutions is meant to be the prime point of contact when the support from Cuban TRC is needed. Their range of expertise covers post disaster reconstruction, disaster resilient social housing, production of "green" construction materials, investigation of materials and construction systems and LC3 fully embark on the overall offer that Ecosolutions can develop in that context.

It is in our view crucial to expand know-how of LC3 over the world in parallel and even before the approval of enabling standards and building codes. It is precisely the knowledge of the potential impacts and technical features of LC3 which will trigger and support the standardisation/other regulatory processes.

Elements specific to other countries

In some countries, cement production is regulated by standards that are based on the performance of the product rather than on its composition. These standards are compatible with the usage of blended cement, whatever the type of clinker substituent, provided that the resulting performance of the blended cement is equivalent or superior to the cement it is mean to replace. Having standards based on product performance is clearly the best way to enable clinker substitution and reduce the CO_2 emissions from the cement manufacturing process. That was one of the policy asks that the cement sector had put forward in the run-up of the COP21 in Paris (that led to the Paris Agreement), when it developed its Low Carbon Technology Partnership initiative (LCTPi), stating on that subject that the need was to "develop new, or revise existing product standards and codes in some countries to allow more widespread use of blended cement, for example, basing standards on performance rather than composition, and ensuring they are accepted by local authorities." This statement raises another concern that goes beyond the elaboration of standards that can accommodate the use of cements with reduced clinker content, but which also deals with construction and building codes that should also recognize the possibility and performance of these new types of materials.

d. Impact

The impact of the LCC project is assessed as "very high".

The strong body of scientific evidence generated by the project and the high visibility of the project in the cement sector are crucial for the adoption of LC3 by global and national cement companies. LC3 is now high on the innovation agenda of many global and local cement producers. The acceptability of using slag and fly ash as clinker substitutes took numerous years (about 20), demonstrating the conservatism of the sector. The achievements reached in about 6 years on LC3 is remarkable and recognized by many in the global cement sector.

Main conducive factors which influence cement companies to consider investment into LC3 are the following:

- Raw material strategy: preservation of (permitted) limestone reserves, anticipation on a future local/global scarcity (and increasing costs) of main clinker substitutes (notably blast furnace slag and fly ashes from coal-fired power plants), insufficient clinker production capacity to sustain growing market demand, etc. Globally, when market demand is robust and increasing, and the current production does not match the current and expected demand for cement and concrete, developing infrastructure for producing LC3 is less CAPEX intensive than developing a full new clinker line, while preserving the limestone reserves and emitting less CO_2.
- Cost reduction: expectation of potential cost savings vs. current product mix.
- CO_2 emission mitigation strategy, to fulfil companies' own mitigation targets, locally applicable climate-related legal requirements and objectives (including financial ones in some countries where a tax on CO_2 or an ETS exists or is planned in a near future).
- The LCC project outcomes as well as the efforts to increase awareness of LC3 have played a central role to encourage companies to consider this option.

Main hindering factors which restrain cement companies to invest today into LC3 are the following:

- Obstacles related to (inexistent or unsatisfactory) standards/building codes.
- Lack of availability of clays of appropriate quality in close vicinity of the plants.
- Lack of internal technical know-how about clay calcination processes, installations, required quality controls. This knowledge should notably be gathered from the ceramics and clay industry and on that purpose, cement manufacturers need to look outside of their traditional stakeholders. It is obvious that technology providers will play a crucial role to address this remaining hurdle for deployment (see below).
- Expressed limited remaining concerns related to technical properties of LC3 (early strength, workability, durability).
- In some regions, negative perception of clays as building material (in terms of quality and durability, and possibly in terms of color of the finished product).
- Financing of required investments.
- Limited awareness on the existence and properties of LC3

The traditional machinery providers for cement kiln lines do not necessarily have the knowledge and the appetite to move rapidly towards developing and providing machinery for calcining clay. Indeed, they still enjoy a robust market for their traditional products, for which CAPEX expenditure is higher than for machinery related to calcined clay and they could even try to communicate negatively or minimize the potential impact of LC3 to maintain a kind of status quo context. However, history has demonstrated in various economic sectors that change is often initiated by disruptors and the traditional stakeholders that manage to remain in the market are the ones that are capable or rapidly adapt. The technology providers we met in India during our Project Review initiated recently an internal innovation project related to clay calcination technologies for LC3 production.

The same comments apply to the chemical companies producing additives for cement and concrete. Some new additives, specifically tailored or the use of LC3 will have to be designed, developed and marketed.

- In some countries with excessive capacity, the potential of LC3 to mitigate CO_2 emissions will be less immediate and attractive as some plants will have to simply close to reduce the existing capacity, sometimes at the request of their governmental authorities. However, this should be considered as an opportunity in some regions as the kilns for which the clinker production is stopped can be used for initial (national) testing for calcined clay production
- Finally, companies that are used to substituting traditional fossil fuels with alternative ones, and for which a market context for these alternative fuels (recovery, collection, pre-treatment, …) is existing could be reluctant to integrate the production of LC3 as an opportunity. Indeed, clay calcination is happening at lower temperatures than clinker production and as such, reduces the types of alternative fuels available for usage in this process. The lower required temperatures reduce the energy demand versus clinker production. Alternative fuels do have a lower (or even sometimes) negative cost for cement companies, which is justified by the waste treatment service provided by these companies while co-processing waste-derived fuels. Developing and implementing a calcined clay production line (although cheaper than a clinker kiln line) might thus result in higher costs for the company due to lower use of alternative fuels.

The potential of CO_2 emission mitigation through the transition to calcined clay cements amounts to around 30% (versus ordinary Portland cement), which is very high compared to the mitigation potential related to the use of alternative fuels (in order to achieve a 30% reduction, one should actually have to use a fuel mix integrating biomass-based alternative fuels up to around 75%, which is exceptionally high; a 100% alternative fuel rate with non-biomass waste-derived fuels will not deliver at all the same level of mitigation). This mitigation potential is not enough present in the minds of industry and decision makers so a strengthened communication needs to be displayed.

- Depending on the type of clay and on the process optimization, the final color of LC3 might be different and have a red/pink component (where traditionally the color grey is associated with cement strength in consumer perception). Although it could be considered as an advantage for some applications, it could also be considered as a blocking point for others. Nevertheless, some tests (particularly done in Cuba) demonstrated that some solutions exist to produce final product with colors comparable to traditional cement, including by fine tuning the quantity of oxygen in the calcination process.
- Potential higher demand for water can be considered as a hindering factor. Additional tests might be needed, particularly with new specific additives (plasticizers) that may reduce this extra water consumption.

We assess the strategy applied by the LCC project on the Aalborg patent issue as appropriate and efficient. It resulted in an outline agreement with Aalborg Cement which is balanced and enables implementation in the country. It is expected to be signed in the next months.

The LCC project has been reaching out to target beneficiaries. These efforts must be sustained to ensure adoption by the construction sector and additional beneficiaries.

The various tests and applications made with the use of LC3, including the demo structure “Tennaza” in La Havana and other building tests in India have demonstrated that the concrete made with LC3 does not produce any cracks, contrary to traditional cement. This property should help build the strength reputation of that type of material to general public.

e. Sustainability

The sustainability of the LCC project is assessed as "high".

Indeed, the potential of the product itself (lower CO_2 emissions, better management of existing resources, affordable applications in housing and infrastructure, lower CAPEX for industrial set-up) is very high in terms of sustainability. However, at this point in time, the level of implementation to deliver the above "very high" level of sustainability is still at risk as the next three years will be critical to ensure its success (or not). For these reasons, we consider the sustainability of the LCC project itself is high, while the one of the product (LC3) is very high :

Based on collected information and expressed opinions of cement producers and key stakeholders, the future of LCC/LC3 cements look promising provided that remaining obstacles or open issues (notably related to standardisation processes) are favourably solved and that adoption by the market is supported by targeted activities (see chapter related to recommendations for future work). In particular, the awareness of the availability and the performance of LC3 cement must be highly communicated not only to traditional cement producers to offer them the possibility to develop a new product in their portfolio but to the whole value chain of the construction business.

These positive expectations clearly result from the activities, scientific/technological outcomes, credibility and high visibility of the LCC project team over past few years.

The body of scientific evidence generated by the project overall convinced many cement companies of the interest and feasibility of the production and use of LC3 as one of the available solutions to address several of their business challenges (essentially: raw material strategy, cost reduction, CO_2 mitigation). An actual industrial scale deployment will require to sustain this conviction by all necessary framework conditions (standards, local availability of appropriate clay types, availability and cost of production equipment, acceptance of users, support from public authorities, …).

The implementation of LC3 will ultimately contribute to reduce the global production and use of Portland clinker (versus a "business as usual" scenario), the most energy- and CO_2 intensive component of cements, in buildings and infrastructure with positive consequences on resources use and CO_2 emissions. It will address the growing scarcity of cement grade limestone reserves observed in many regions. The environmental impacts of the extraction and processing of clay must obviously be addressed. Robust management, operation, monitoring and control processes must be enforced in order to minimize negative impacts: land use, protection of biodiversity, transport, energy efficiency, emissions, etc.

The project benefits are clear but efforts must be sustained to help accelerate implementation at industrial scale in a traditionally conservative, fragmented and highly regulated construction sector.

Recommendations related to further activities in Phase 2 and a potential Phase 3 (objectives, activities, project set-up) are formulated in a following section of the present report. The financial support, reputation and international network of SDC are in our view essential success factors to accelerate effective implementation over the next few years.

f. Global SWOT analysis

S

LC3 has clear advantages on the three pillars of sustainable development

- Environment:
  - Reduction of CO_2 emissions (up to 40% compared to OPC) through clinker substitution
  - Reduction of limestone resource usage
  - Higher long-term strength (resilience)
- Social:
  - Capacity of affordable housing opportunities in developing countries, economic development
  - Applications for coastal areas to flight against sea water deterioration
- Economic
  - Illimited resources of clay available
  - Lower cost than OPC
  - CAPEX costs can have a rapid ROI
  - Some existing kilns can be used to calcined clay (even if not optimum)

Existing standards for blended cements can accommodate LC3 in their categories
Tests are all conclusive and knowledge should be widespread
Technical Research Centers have demonstrated efficiency and built trust
LC3 is a new type of product, complementary to other blended cements and not competing with them

W

Wide communication is still behind requirements
Cement industry not yet fully aware about potential of LC3 to reduce CO_2 emission
So far, big cement manufacturers have not embarked on LC3 as part of their future strategy
Suppliers of machinery and additives not yet involved in the LC3 development opportunity
Standardization process can take long in some countries (3 to 5 years)
Cement industry is rather conservative (fly ash application took 20 years)
Lack of long-term experience on the use of LC3
Reputation of clay (perceived as less robust than limestone), whereas the combination of the two is stronger
No uniform color of calcined clay
Higher water demand

O

Change/transition in Cuba with high investment in construction and limited limestone resources
Other countries to embark on the same path
Extension of limestone quarries; better use of limited limestone deposits
Government promotes renewable energy which will limit the available quantity of fly ash in the future
Transfer and dissemination of knowhow and experiences to other countries and regions
Opportunity to get access to financial resources due to the innovative and CO_2-reducing character of the project

T

Red color of the cement/concrete
Increase of water demand which might hamper the acceptance of LC3 by the construction companies
Higher degree of carbonation
Industry and decision makers not aware enough of the huge impact and potential in CO_2 mitigation of LC3
- Lack of acceptance by the user (e.g. builders)
- clay price (will it increase?)

Limited experiences with the production of LC3 cement might result in reduced cement output
Lack of commercial interest by some cement companies

8. Recommendations for future activities

Based on the above analysis, the Review Team elaborated a series of recommendations for the remaining part of the LCC Project's Phase 2 as well as for the continuation with a Phase 3, which are described in more detail below.

The project is at a cornerstone of its history and needs to move towards a **holistic support to real industrial-scale deployment** in order to deliver identified environmental/economic and social benefits.

> *At this stage, the Review Team considers that putting an end to the project after Phase 2 still runs a major risk that the product never reaches commercial level and/or remains a niche product without delivering its full social (affordable housing, adaptation, resilience), environmental (CO_2 emissions reduction, resources availability and preservation) and economic (opportunity for economic development) potential.*
>
> ***The Review Team recommends therefore to design and implement a third and final project phase of 3 years (concluding by 2023 end) with a focus on "catalyzing business deployment" in order to ensure the sustainable establishment of LC3 as a reliable, viable and green cement at global scale**, and to use the remainder of phase 2 to prepare appropriate initiatives included under phase 3, so that their deployment can be launched as soon as Phase 3 starts in June 2020.*

Consequences for the remaining part of Phase 2

For the remaining months of phase 2, the review team recommends the project team to focus on the successful completion of the activities foreseen in the project document. Specifically, this entails but is not limited to

- maintaining an active role by addressing producers' concerns related to LC3, particularly on early strength, long-term durability and additives (Technical Resource Centers); no long-term experience exists with the use of LC3 so some accelerated tests could be envisaged to simulate the aging performance of LC3-based materials and applications

- accompanying the commissioning of the planned pilot production sites and providing support in case technical challenges experienced in the initial phase after commissioning of those sites (Technical Resource Centers);

- documenting project learnings and key data gathered from the pilot phases and the first industrial production campaigns and make sure that SDC gets the necessary credits on these materials, where applicable (Project Team);

- developing facts and figures for (non-scientific and non-technical) policy makers as advocacy arguments

SDC should also use the remaining time of phase 2 to initiate the preparation of a subsequent and final phase 3, including the identification of the appropriate project setup and project partners. It should focus on 3 points:

- **preparation of content**: development of advocacy arguments (facts and figures) and key data gathered from the pilot phases and the first industrial production campaigns,
- **identification partners**: identification and first contacts with potential partners in the various countries.
- **composition project teams for Phase 3**: putting in place the right set of skills to lead and execute Phase 3 activities,

Focus of the third and final project phase: catalyzing business deployment

As the cement/concrete and construction sectors are slow-moving (high capital intensity, importance paid to traditional practices, strongly regulated sectors, …), the transition from laboratories and pilot tests to industrial scale production commercial development requires a **catalyst** with some external investment to be considered for the following years (over the period 2020-2023).

During this period, several enabling standards will hopefully be adopted, some major cement manufacturers will be visibly engaged, first applications will be implemented, key stakeholders will be mobilized to endorse and support the move towards LC3. One should aim at cement production volumes in the order of **millions of tons** (which is the relevant order of magnitude to assess deployment in the cement business) by the end of the period.

A successful phase 3 requires building on the excellent body of evidence built to date by the project team and the TRCs as well as on the high visibility and awareness achieved thanks to the commitment of project team members and their partners.

But it also requires a more **holistic approach**, where cement and concrete technological aspects continue playing an active role as one of the key success factors together with additional aspects of marketing and sales, manufacturing and technological innovation (particularly for adapted chemical additives). The Review Team recommends that the work of the Phase 3 focuses on the industrial-scale deployment and commercial implementation of LC3 as a mainstream cement and does not extend the scope of the project to other CO_2 mitigation options (as some stakeholders suggested - such as increase use of alternative fuels for instance). In our view, Phase 3 should be the last phase of the LCC project, before full take over by private players. Its only aim should be to have LC3 deployed as a mainstream product. It is essential that all available resources are channeled towards this objective.

Obviously, the higher the available resources, the higher the chances of success for this phase 3. Additional funding could be envisaged, especially for local implementation and development; financial institutions like the International Finance Corporation (IFC) or the regional Development Banks (EBRD, ADB…) should be considered and if/when a few or several investors are involved in the project, an updated governance will have to be established to match this new financial structure. As the technology is now sufficiently mature (with all tests conducted and evidence established) to be implemented at scale, as the potential is particularly relevant to fast growing and developing countries (although also existing in mature markets), and as the emissions reduction is signifivative, the LC3 product could be one right candidate for being supported by these development banks.

Four main work packages for Phase 3

The review team identified four work packages **as key elements** for Phase 3:

1. Support standardization processes: enabling standards are crucial for future deployment. One should define clear action plans in the various target countries to ensure a successful outcome of standardization processes, considering active engagement with most relevant local stakeholders (example of the NCB in India, which seems instrumental there to help address concerns related to carbonation risks). One of the main challenges related to the ongoing standardization process is to avoid limitations in the use of LC3 as well as strict limitations on clinker substitution rate which would strongly reduce the incentive for companies to proceed to market deployment and considerably decrease the contribution of these cements as a solution to sustainability challenges (crucially, climate change). An excessive pressure to accelerate the process might result in tougher limitations related to the applicability of LC3 (confining them to precast products without reinforcement or masonry mortars). The tasks that

the cement sector developed in the run-up of the COP21 in Paris should be emphasized and supported by key cement manufacturers in the respective regions.
In parallel, adapting construction/building codes to recognize the existence and potential of LC3 should be considered, with a clear communication to raise awareness and build capacity towards the community of architects, builders and developers.

2. Engage with technology suppliers and admixtures producers

- **to enhance innovation on new machinery (calciners) and additives (specific to LC3 and clay)**
- **to make sure that cement manufacturers can build their business case for investment projects.**

So far, big traditional machinery manufacturers and chemical producers (for additives) have developed their products for supporting the technical and commercial development and sales of different types of cement, based on limestone, clinker and established clinker substitutes. Although some of these products could be used for the future production of LC3, they are not yet optimized and the quantity to be used (for additives for instance) could increase the cost of the final product or induce some unwanted properties for LC3 (higher water demand for instance). In addition, the specificity of clays in their handling induce that some existing machinery is less adapted to the production of LC3. This is the case when using a dryer or a vertical flash-calciner. Therefore, information and knowledge from the clay industry should be shared with these manufacturers so that they identify LC3 as a new market opportunity and further deploy innovation efforts to produce adapted machinery and additives, optimized for the production of LC3. As the current market for more traditional products is still strong, it might be challenging to convince them to actively support the transition to LC3. Early movers shall be identified to initiate the process.

Some cement manufacturers clearly indicated that they would need some support to accompany them towards the production of these new products. Although the project's aim is not to develop feasibility studies on behalf of the cement manufacturers, the project can establish relationship between different stakeholders, as a catalyst for accelerating the production of LC3 by these manufacturers.

From that perspective, the final aim of Phase 3 should be to establish an ecosystem of suppliers and experts around LC3 which could support cement manufacturers at each step of their transition. On a side note, Sika, as one one of the leading producers of admixtures could also add Swissness to the project, in line with SDC's strategy to engage with the private sector and promote Switzerland's added value in its projects.

3. Enhance awareness, share knowledge, build reputation

As of today, a lot of tests have been carried out in laboratories and pilot plants to identify the various characteristics of LC3 and its possible application in concrete. These tests have been carried out in different types of countries and with different types of clay. Although a few minor additional tests might be needed, on a case-by-case basis, the Review Team (on the basis of its analysis) consider that sufficient knowledge and know-how has been established and that the focus should now be established on sharing this information to a wide majority of stakeholders (producers, authorities, market influencers…). One key target of this exercise would be to foster demand for LC3. When stronger demand raises, the LC3 will then become rapidly a mainstream cement and the project itself would then be fully sustainable on its own.

The following points must be considered to design the awareness raising and knowledge sharing activities:

- Clay reputation improvement (mixed with limestone and clinker):

So far, clay as a construction material is considered by some stakeholders as a product of poor quality with reduced strength and limited durability. It is important to mention that LC3 is a combination of clay, limestone and clinker providing similar or better performance than OPC.

- Specific benefits of LC3 (coastal areas for instance) should be highlighted.

- One should engage with local associations (cement, concrete, construction, …) as well as with established building experts, architects and developers. These stakeholders are crucial market influencers and LC3 ambassadors.

- Focused articles on specialized magazines as well as on social media could enhance knowledge on the product and promote successful existing projects in order to provoke a snowball effect.

- Commercial and technical presentations could be considered in major regional congresses organized by regional trade associations. These forums should be used to enhance awareness and have separate discussions with machinery and additive manufacturers that regularly have booths in the exhibition area besides the forum and are sponsors of the events.

4. Develop and implement high-level advocacy

The active support of **public authorities and financial institutions** (development banks, foundations, green funds…) is essential to boost deployment. An active and consistent advocacy approach should target these 2 groups of stakeholders in the various countries where the project operates.

This requires the development of environmental and social facts and figures (impact on employment, CO_2 emissions, adaptation to climate change, circular economy, …). This database should be a living document and be regularly updated as long as some additional information, experience is accumulated. The project should not wait to have a full comprehensive database available to initiate the process but should start and complement the contents of the database throughout the different advocacy campaigns.

This also requires an identification and prioritization of critical local stakeholders (the existing network of SDC will undoubtedly be helpful in this respect). For example, in India, private institutions TERI or government-owned think tank NITI Aayog could play an instrumental role to create buy-in at the relevant public authorities and Ministries to actively support the deployment of LC3. A tracker shall be implemented to identify the potential benefits generated by this advocacy program.

Team and organization

The required set of skills to design and execute Phase 3 activities is significantly broader than those mobilized during the first 2 phases.

Ideally, in each of the key countries, a businessperson with strong local reputation in the cement/construction sector should lead a team encompassing public advocacy/marketing and technical profiles. In other words, the Review Team proposes to build on the experience of established Technical Resource Centres, which should become LC3 Resource Centres aiming at catalyzing industrial scale production and commercial deployment.

A global team should coordinate efforts and provide adequate support to local teams in terms of technical knowledge, facts, figures and interactions with international stakeholders. This team should include practitioners, advocacy experts and technical professionals (both on

production process technologies and on cement/concrete technology). Ideally, the proposed organization would also have the capacities to sustain this role beyond the project duration.

Although the context of each and every country is specific, there might be some common ground between the different countries' approaches, for which a global coordination and experience sharing process may prove to be efficient and prevent from repeating similar actions in various places. As a consequence, the expertise and experienced developed by EPFL, UCLV and the TRCs in the two first Phases is important and this expertise should be the foundation for the new broadened approach, going much beyond cement and concrete technology aspects.

Annex 1

List of Abbreviations

2DS	2-degree scenario
CCUS	Carbon Capture and Utilisation or Storage
CIDEM	Centro de Investigación de Materiales Cuba
CMA	Cement Manufacturers Association (India)
COP	Conference of the Parties
CSI	Cement Sustainability Initiative, one of the flagship sectoral projects of WBCSD
DAC	Development Assistance Committee (of OECD)
ECRA	European Cement Research Academy
EPFL	Ecole Polytechnique Fédérale de Lausanne
ETS	Emissions Trading Scheme
FICEM	Federación Interamericana del Cemento
GCCA	Global Cement and Concrete Association
GDP	Gross Domestic Product
GPCCE	Global Programme Climate Change and Environment
IEA	International Energy Agency
IIT	Indian Institute of Technology
LCC	Low Carbon Cement
LC3	Limestone Calcined Clay Cement
LCTPi	Low Carbon Technology Partnership initiative
LH	LafargeHolcim
NCB	National Council for Cement and Building Materials (India)
NDC	Nationally Determined Contributions
NGO	Non-Government Organization
OECD	Organization for Economic Co-operation and Development
OPC	Ordinary Portland Cement
PCA	Portland Cement Association
RTS	Reference Technology Scenario
R&D	Research and Development
SDC	Swiss Agency for Development and Cooperation
SDG	Sustainable Development Goals
SWOT	Strengths, Weaknesses, Opportunities and Threats
TARA	Technology and Action Rural Advancement
TERI	The Energy and Resources Institute (India)
TRC	Technical Resource Center
UCLV	Universidad Central de Las Villas (Cuba)
UNEP	United Nations Environment Program
VDZ	Verein der Deutschen Zementindustrie (Association of German Cement Producer)
WCA	World Cement Association
WBCSD	World Business Council for Sustainable Development

Annex 2

Assessment dimensions and criteria prescribed by the OECD

a) Relevance

- How does the LCC project phase 2 contribute to the objectives set in SDC's strategic framework of the Global Cooperation on Climate Change?
- How does the LCC project fit in with national level development priorities of the partner countries (India, Cuba and others) and global agenda on environment, climate change and related concerns?
- Is the LCC project well accepted by key stakeholders to address the challenges faced by the cement sector?
- Is LC3 coming out as a realistic option in comparison to other alternatives commonly used by the cement industry?
- Is LC3 of interest to the government / public sector entities as reliable, viable and green cement which can contribute to meeting their global commitments on reducing CO_2 emissions?
- What are the challenges and limitations for LC3 over other green cements available in the market or other technologies geared towards reducing emissions from the cement sector?

b) Effectiveness

- Are the project goals and approach meeting the sectoral needs?
- Has the approach of the LCC project been effective in achieving the project outputs and outcomes?
- To what extent has the LCC project achieved its stated objectives and intended impacts?
- How effective is the project set-up? Does the project work with the right partners to achieve the stated objectives and intended impacts?
- Is the technical assistance provided through Technical Resource Centers (TRCs) adequate to support the cement industry?
- How effective is the dissemination approach (promoted by the project and CEMENTIS) for the LC3 technology to rope in the cement industry for its production and application? Are the business plan of TRCs sustainable?

c) Efficiency

- Have the project resources been used in an efficient manner to achieve the project objectives? Have the project activities been implemented in a timely manner and within the proposed budget?
- Has the project been able to leverage proposed resources for implementing the project activities and sustaining project initiatives beyond the Phase-2?
- How have the project implementing agencies coordinated their efforts with relevant stakeholders including the cement industry, standard setting agencies, builders to promote production and use of LC3?
- Is it efficient to expand know-how of LC3 technology in several countries without having its standards and building codes approved at the national level?

d) Impact

- To what extent has the project been able to convince the industry to invest its resources in production of LC3?
- What are the conducive respectively hindering factors identified by the cement industry influencing their decision whether or not to invest into LC3?
- How has the project been affected by certain external factors for example, patent granted to Aalborg in India? Was the strategy followed on the patent issue constructive?
- How far has the project been able to reach out to the target beneficiaries such as builders, developers, etc?
- Has the project had any unintended (positive or negative) impact?

e) Sustainability

- Does LC3 face any economic/ financial barriers to becoming mainstream commercial cement?
- Does the project technologically contribute to longer term sustainability of the cement sector in the respective countries and globally?

- To what extent can the LC3 be sustainably produced and used in the long run?
- What are the other likely environmental impacts of the project that are significant to be considered from the cement industry perspective?
- What are the achievements and existing gaps in the approach and how best can the project address them in remaining period?
- Can the LCC project sustain the impact of the project benefits beyond completion of phase 2? What needs to be considered? Additional ideas for a follow-up project are solicited.
- In case, a Phase 3 is recommended, why is SDC support still needed and in what from? The review should also reflect on where the focus of a potential phase 3 should be laid, on what and how? What would need to be the project set-up? Should the project still only focus on the LC3 technology or go beyond (e.g. alternative fuels or others)? Who could be potential partners/co-financers? Through what channels could lessons from LC3 be shared on a global scale?

List of documents provided by SDC to the review team
Desk review

anand.shukla@eda.admin.ch -> p.fonta@scrum-consult.com,Bernard.Mathieu@hop3.eu,andrin.fink@eda.admin.ch

WebFTP

List of files:

Filename	Size
EPFL Half-year_report_ May-Nov2017.docx	1.2 MB
MoM_SC 180205.pdf	681.2 kB
MoM_SC 181008.pdf	516.9 kB
MoM_SC170929.pdf	344 kB
Review Report LCC ph 1.pdf	1.3 MB
Review Report Management Response.pdf	102.6 kB
SDG roadmap for IndianCementSector.pdf	1.7 MB
Cementis Country Attractiveness ver 6.pptx	3.5 MB
Cementis LC3- FS report.docx	3.9 MB
Cementis Quarterly report 310518.docx	131.1 kB
Cementis Quarterly report Dec18-Feb19.docx	314.8 kB
Cementis Quarterly_report_-_June_-_Aug._2018.pdf	1.4 MB
Cementis Quarterly_report_-_Sept_-_Nov._2018.pdf	1.3 MB
Contract Cementis LCC ph 2.pdf	2.4 MB
Contract EPFL with ProDoc Ph 2.pdf	3.7 MB
Credit proposal LCC Ph 2.pdf	1006.6 kB
EPFL annual report Jun17-May18.pdf	1.4 MB
EPFL half-year report_Jun18-Nov18.pdf	1.2 MB

Annex 4

List of organizations / people / institutions met

General:

- Karen Scrivener (EPFL)
- Markus Akermann (Independent, former Holcim CEO, Member of LC3 Advisory Board)
- Laurent Grimmeisen and Anne de Keukelaere (Cementis)
- Wolfgang Dienemann (HeidelbergCement)
- Edelio Bermejo (LafargeHolcim)
- Soumen Maity (TARA)
- Fernando Martirena (CIDEM - CUBA)
- Claude Lorea (GCCA)
- Ian Riley (WCA)
- Esha Sar (Former WBCSD/CSI in India Manager)
- Martin Schneider (VDZ/ECRA)
- Arturo Putin (IPIAC for Ivory Coast project)
- Carlos Ferraro (ASOCEM – Peru)
- Fernando Acosta (NAMA Cemento – Peru)
- Rosaura Vásquez Arrieta (Universidad de Ingeniería y Tecnología - Peru)
- Carlos Aramburo and Maria Isabel Echeverri (Argos)

Cuba:

- Pavel Cancino-Vidal and Sabino Velez-Chirino (Cement Group Cuba.)
- Cecilia Moliner and Elena Tellez (Technical Committee Cement)
- Manuel Vazquez (Low Cost Housing Program. Building Materials Production)
- Miguel Velasco (Prefabrication Enterprise)
- Wilfredo Prieto (Artist)
- Gonzalo Reina (Cementos Siguaney)
- Argelio Abad and Gilberto Alba (Geominera del Centro)
- Osana Molerio, Alina Montero and Luis Barranco (UCLV)
- Maria Velasco (Ministry of Science & Environment)

India:

- S.K. Wali (JK Lakshmi Cement Ltd)
- Mahendra Singhi (Dalmia Bharat Cement)
- Dr Soumen Maity (Team Leader TARA)
- Dr. Debapriya Dutta (Science for Equity, Empowerment & Development (SEED))
- Saurabh Diddi (Bureau of Energy Efficiency)
- Dr. Bibekananda Mohapatra (National Council for Cement and Building Materials)
- Dr Shashank Bishnoi (IIT Delhi)
- Dr. V. Ramachandra (UltraTech Cement Ltd)
- Kaustubh Phadke (GCCA Mumbai)
- Pranav Desai (CDIC & Product Development)
- D. Muruganandam (India Cements Ltd)
- Dr. Sivakumar Kandasami (Larsen and Toubro Limited)
- V.S. Adithya (Tvasta Manufacturing Solutions Ltd.)
- Dr Manu Santhanam (IIT Chennai)
- Anil Kumar Seth (Supertech Limited)
- Dr. Ajay Mathur (TERI - The Energy and Resources Institute)
- Aparna Dutt Sharma (Cement Manufacturers Association)
- Sivaram Krishnamoorthy (International Finance Corporation)

Annex 5

Visit in India (program and people met)

Day 1: Delhi	5th August			
1	S.K. Wali skwali@jkmail.com	Whole Time Director	JK Lakshmi Cement Ltd. Nehru House, 4, Bahadur Shah Zafar Marg, New Delhi. Phone 011 33001142	Overview on LC3 from a cement plant perspective
2	Mahendra Singhi mahendra.singhi@dalmiabharat.com	Group CEO and Whole-time Director	Dalmia Bharat Limited, 11th & 12th Floor, Hansalaya Building 15, Barakhamba Road, New Delhi 110001	Overview on LC3 from a cement plant perspective
3	Shri. Sanjay Pant sanjaypant@bis.gov.in	Director and Head Civil Engineering Department	Bureau of Indian Standards Manak Bhavan, 9, Bahadur Shah Zafar Marg, New Delhi – 110002. Phone: 011 23235529, m: 9818251925	Overview of LC3 and its policy perspectives from a Standards Institution
4	Dr Soumen Maity smaity@devalt.org	Team Leader	TARA Headquarters B-32, Tara Crescent, Qutub Institutional Area, New Delhi 110016	LC3 project partner

Please kindly note that this is a tentative program, that can be adjusted to match people's availability

Day 2: Delhi	6th August			
1	Dr. Debapriya Dutta ddutta@nic.in	Head	Science for Equity, Empowerment & Development (SEED) Division Department of Science & Technology New Mehruali Road, New Delhi - 110016. Mobile: 8130545765, landline: 011 26590595	Overview of LC3 and its policy perspectives from a Science and Technology Department
2	Mr Saurabh Diddi	Director	Bureau of Energy Efficiency 4th Floor, Sewa Bhawan, R.K.Puram, West Block, Rama Krishna Puram, New Delhi, Delhi 110066	GoI initiatives on energy efficiency in various sectors including the cement sector.
3	Dr. Bibekananda Mohapatra nccbm@ncbindia.com	Director General	National Council for Cement and Building Materials 34 Km Stone, Delhi-Mathura Road (NH2), Ballabgarh-121 004, Haryana, INDIA	Overview on LC3 from standard institution perspective
4	Dr Shashank Bishnoi shashank.bishnoi@gmail.com	Associate Professor	IIT Delhi Hauz Khas, New Delhi 110 016	LC3 project partner
	Evening Flight to Mumbai			

Please kindly note that this is a tentative program, that can be adjusted to match people's availability

Day 3: Mumbai	7th August			
1	Dr. V. Ramachandra ramachandra.v@adityabirla.com	Head-Technical Services	UltraTech Cement Ltd "B" Wing, 2nd floor, Ahura Centre Mahakali Caves Road, Andheri (East) Mumbai 400 093, India	Overview on LC3 from a cement plant perspective Office: Secy Ms Rashmi: 022 66917384
2	Kaustubh Phadke	General Manager	GCCA Mumbai Ahura Centre, Office no. 3, Ground Floor, 82 Mahakali Caves Road, Andheri (East) MUMBAI Mumbai City Maharashtra - 400093 India. Mob: 0091 9833053965	GCCA plan of action in coming months/year
3	Pranav Desai pranav.desai@nuvoco.in	VP , Head - CDIC & Product Development	Construction Development & Innovation Center NUVOCO Vistas Corp. Ltd, Construction Development & Innovation Center ,Unit No. 13, Compartment No. 42, Marol Co-operative Industrial Estate,Marol, Andheri (East), Mumbai-400059.	Overview on LC3 from a cement plant perspective Office: 022 614101102 (direct) Secy Ms Supriya: 022 614101101
	Evening flight to Chennai			

Please kindly note that this is a tentative program, that can be adjusted to match people's availability

Day 4: Chennai	8th August			
1	Mr. D. Muruganandam muruganandam@indiacements.co.in	Technical Director	India Cements Ltd Coromandel Towers, No: 93, Santhome High Road, Karpagam Avenue, R.A.Puram, Chennai - 600028.	Overview on LC3 from a cement plant perspective
2	Dr. Sivakumar Kandasami drks@lntecc.com	Concrete Technologist	Larsen and Toubro Limited P.B, No.979, Mount Poonamalle High Rd, Chennai, Tamil Nadu 600089	Industry viewpoint
3	V.S. Adithya adithyavs@tvastagroup.in	Founding Partner	Tvasta Manufacturing Solutions Ltd. EID 317, IIT Madras Campus, Velachery, Chennai, Tamil Nadu, 600036, India	3D printing of concrete structures using LC3
4	Dr Manu Santhanam	Professor	Indian Institute of Technology Madras Indian Institute Of Technology, Chennai, Tamil Nadu 600036	LC3 project partner
	Evening flight to Delhi			

Day 5: Delhi	9th August			
1	Mr. Anil Kumar Seth	Executive Director	Supertech Limited B 28-29 Supertech House, Sector 58, Noida, Uttar Pradesh 201307	Perspective of LC3 user i.e. product manufacturing
2	Dr. Ajay Mathur	Director General	TERI - The Energy and Resources Institute 6C, Darbari Seth Block, India Habitat Center Complex, Lodhi Road, New Delhi, Delhi 110003	
3	Ms Aparna Dutta Sharma, Secretary General/ Dr. S.K. Handoo sk.handoo@cmaindia.org	Advisor (Technical)	Cement Manufacturers Association 3rd Floor, Plot No. 7, Vasant Kunj Institutional Area, Vasant Kunj II, New Delhi 110070	Perpective from cement manufacturing association of India
4	Sivaram Krishnamoorthy skrishnamoorthy2@ifc.org	Operations Officer	International Finance Corporation Indira Gandhi International Airport, Worldmark 3, 6th Floor, Asset No 7, Aerocity, Near, New Delhi, Delhi 110037	Financing perspective of LC3
5	Meeting at SDC with Anand Shukla		Embassy of Switzerland, Nyaya Marg, Chanakyapuri, New Delhi	Debriefing

Conclusions :

- Very positive feedback, optimistic for the future of LC3
- Recommendations for next steps

Completion of the standardization process (1 to 3 years)
Additional reassurance
External pressure
Additional research & innovation work (raw materials, additives, real scale)
Technico-commercial approach (handholding cement producers)
Awareness programme and knowledge sharing activities
Advocacy (governmental organisations and big building organisations)

Annex 6

Visit in Cuba (program and people met)

Date	Activity	Coordinated with People met			Comments
25.08.2019 Sunday	Arrival in Habana				
26.08.2019 Monday	8:30: Transfer to Santa Clara (300 km)	CIDEM			
	14:00: Planning and making interviews at CIDEM	Fernando Martirena	Project manager	General coordination	All activities within Universidad Central Las Villas (UCLV)
		Adrian Alujas	Senior scientist	Scientific advisory/coordination	
		Elizabeth Cabrera	PhD student #1	Carbonation induced corrosion	
		Maria B. Díaz	PhD student #3	LC3 in concrete applications	
		Karina Duverger	PhD student #4	Early age hydration of LC3 cement	
		Guillermo Esperanza	Expert	LC3 pilot plant	
		Yudiesky Cancio	Postdoc	Impacts	
		Eilys Valdes	Mr.Sc. Student	Durability of concrete	
		Anet Leyva	Mr.Sc. Student	Economics	
		Sofía Sánchez	Postdoc	Impacts	
		Yosvany Díaz	PhD co-supervisor	Durability	
		Dania Betancourt	PhD co-supervisor	Mortars	
27.08.2019 Tuesday	9:00: Reception at UCLV	Alina Montero	UCLV	Head of International Affairs	
		Luis Barranco	UCLV	Vice Rector for Science	
	10:00: Visit to prefabrication workshop Remedios (40 km from SCL).	Miguel Velasco			LC3 girders for bridge offshore Interview with LC3 users
	14:00: Visit to the LC3 Pilot Plant at UCLV.	Argelio Abad	Geominera del Centro	General Director	LC3 production
		Gilberto Alba	Geominera del Centro	Director Plant LC3	

	am: Transfer to Habana				
28.08.2019 Wednesday	am: Meetings at Ministry of Construction	Odalis Sanchez	Technical Committee 22 (cement)	President	All cement people Standards and implementation in Cuba (housing program)
		Sabino Velez-Chirino	Cement Group Cuba.	Technical Chief	
		Humberto Valle	Direction for Quality. Ministry of Construction	Director	
		Ernesto Juncosa	Consortium for Materials. Ministry of Construction	Head of Business Office	
		Miguel Cabrera	Low Cost Housing Program. Building Materials Production	Deputy Director	
		Juan Pablo Ruiz	Prefabrication Enterprise	Technical Chief	
	pm: meetings with architect				
29.08.2019 Thursday	Travel to Guatemala				

Conclusions :

Overall very positive:

- **Technical Resource Center** has sound technical and economical capacities and a cost recovering business model, equal gender representation in the team
- Strong collaborative spirit and a lot of initiative, proactively **seeking synergies** (among TRCs, within SDC, within Cuba), successfully contributing to dissemination
- The **arguments** to support LC3 usage are social and not environmental

Need to enhance housing and infrastructure in the country
Huge potential for coastal areas (strength, no cracks like with traditional concrete)
Embargo with Cuba (optimizing resources, difficulty to engage with partnerships or import materials)
We had to ask the question about CO_2 at the ministry of construction

- **Standard-setting** process OK, Ministry of construction very supportive

Annex 7

Other visits: Guatemala and Punta Cana (program and people met)

Date	Activity	Coordinated with People met			Comments
29.08.2019 Thursday	Arrival in Guatemala City				
30.08.2019 Friday	8:30: Transfer to Plant La Pedrera (Cementos Progreso)				
	9:00: Meeting with Cementos Progreso and visit of the Lab and Research Center	Aldolfo Gramajo	Project manager	General coordination	
		Luis Velasquez	Senior scientist	Scientific advisory/coordination	
		Elizabeth Cabrera	PhD student #1	Carbonation induced corrosion	
		Maria B. Díaz	PhD student #3	LC3 in concrete applications	
		Karina Duverger	PhD student #4	Early age hydration of LC3 cement	
	Lunch				
01.10.2019 Sunday	Travel to Punta Cana – Dominican Republc (FICEM)				
02.10.2019 to 05.10.2019	Various meetings besides the FICEM Technical Congress	Maria-José Garcia	Executive Director	FICEM	
		Alejandro Ramírez Cantú	CEMEX	Président FICEM	
		Adriano Brunetti	DOMICEM	Executive Director	
		Mario Orellana	Cementos Progreso		
		Ricardo Pareja	Melón FICEM	Head of Ficem Technical Roadmap	
		Yassine Touhari	On-field Research		
		Carlos Ferraro	ASOCEM (Peru)	Executive Director	
		Francisco Barrrera Arias	YURA S.A	Operations Manager	
		Fredy Zevallos Quiroz	YURA S.A.	Process control and Development Specialist	

		Camillo Sanchez	CEMEX	Sustainability Manager South America, Central America & Caribean	
		Cesar Pedrajas and Carlo Aramburo	ARGOS	Involved in LC3 project in Colombia	
		John Kline	Kline Consulting	Former Cement leader	

Key Aspects based on DAC criteria		Score (choose only one answer for each question)	Justification - compulsory (please write a short explanation with the main points and refer to the chapter(s) where the information that justify your assessment can be found)
Assessment of relevance			
1. The extent to which the objectives of the SDC projects/programmes are consistent with the demands and the needs of the target groups (incl. gender-specific requirements).	☐ ☒ ☐ ☐ ☐	*Very good: Fully consistent* *Good: Largely consistent* *Poor: Only partly consistent* *Bad: Marginally or not at all consistent* *Not assessed / Not applicable* [1]	Chapter 7.a – climate change mitigation is an important need addressed by the project
2. The extent to which the objectives of the SDC projects/programmes are consistent with the demands and the needs of partner country (institutions respectively society) as well as the sector policies and strategies of the partner country	☒ ☐ ☐ ☐ ☐	*Very good: Obvious consistency with demands and needs of society and in line with relevant sector policies and strategies*[2] *Good: Consistency with demands and needs of society and in line with relevant sector policies and strategies* *Poor: Consistency with demands and needs of society not visible but in line with relevant sector policies and strategies* *Bad: Not consistent* *Not assessed / Not applicable* [1]	Chapter 7.a – project contributes to Paris Agreement (climate change mitigation and adaptation through better resilience) and SDGs (affordable and resilient housing and infrastructure, local production and consumption…)
3. The extent to which the design of projects/programmes is adequate to achieve the goal and objectives (definition of target groups; choice of approach and operational elements; articulation of components; choice of partners; consistency with SDC policies and experiences).	☐ ☒ ☐ ☐ ☐	*Very good: Fully adequate* *Good: Largely adequate* *Poor: Only partly adequate* *Bad: Marginally or not at all adequate* *Not assessed / Not applicable* [1]	Chapter 7.a – LC3 is not only pushed for climate reasons, but also for its co-benefits (extension of traditional raw material resources, lower costs, development capabilities in fast-growing countries..)
Assessment of effectiveness			
4. The extent to which the planned objectives at outcome level have been achieved taking into account their relative importance. If possible, distinguish the quality and quantity of results achieved.	☐ ☒ ☐ ☐ ☐	*Very good: Fully achieved or overachieved* *Good: Largely achieved* *Poor: Partly achieved* *Bad: Marginally achieved* *Not assessed / Not applicable* [1]	See Executive Summary and Chapter 7.b. The volume of cement produced so far allows only a qualitative assessment that should be completed quantitatively with the upcoming plants
5. The extent to which the projects/programmes contribute to poverty reduction, inclusion and/or reduction of vulnerabilities.[3]	☐ ☒ ☒ ☐ ☐	*Very Good: Strong evidence of contribution* *Good: Evidence of contribution* *Poor: Few evidence of contribution* *Bad: No contribution* *Not assessed / Not applicable* [1]	Benefits are rather indirect, but potentially more visible in the future. However, in Cuba for instance, the LC3 product is seen as providing affordable and resilient application (coastal areas))

[1] This category applies a. if the ToR of the evaluation explicitly exclude the assessment of the criteria and/or of the key aspect(s) or b. if there is no information available to assess the criteria.
[2] The policies and strategies should not be in opposition to the needs of the society (applies mainly in governance and human rights).
[3] Dimensions for consideration are: a) economic (income and assets); b) human capacities (health, education, nutrition); c) ability to take part in society (status and dignity); d) political capacities (institutions and policies); e) resilience to external shocks.

6. The extent to which the outcomes achieved contribute to improved governance from a system perspective.[4]	☐ ☐ ☐ ☐ ☒	*Very good: Strong evidence of contribution* *Good: Evidence of contribution* *Poor: Few evidence of contribution* *Bad: No contribution* *Not assessed / Not applicable* [1]	Click here to enter text.
7. The extent to which the outcomes achieved contribute to gender-specific results.	☐ ☐ ☐ ☐ ☒	*Very good: Strong evidence of contribution* *Good: Evidence of contribution* *Poor: Few evidence of contribution* *Bad: No contribution* *Not assessed / Not applicable* [1]	It is worth mentioning that he teams (EPFL, Cementis, UCLV) represent a good gender balance. This is not one of the "outcomes achieved" or the consequence of the project results
Assessment of efficiency			
8. The extent to which the relation between resources (mainly financial and human resources) and time (e.g. delays compared to planning) required and results achieved is appropriate (Cost-benefit ratio - CBR).	☐ ☒ ☐ ☐ ☐	*Very good: Positive CBR based on a cost-benefit analysis (CBA)* *Good: Positive CBR, based on qualitative justification* *Poor: Poor CBR, based on qualitative justification* *Bad: Bad CBR demonstrated* *Not assessed / Not applicable* [1]	Chapter 7.c – project faced certain delays, to a certain extent beyond the control of the project team (e.g. patent issue)
9. The extent to which the approaches and strategies used by the SDC projects/programmes are considered efficient (Cost-efficiency).	☐ ☒ ☐ ☐ ☐	*Very good: Highly efficient* *Good: Efficient* *Poor: Partly efficient* *Bad: Not efficient* *Not assessed / Not applicable* [1]	Chapter 7.c
Assessment of sustainability			
10. The extent to which the positive results (outputs and outcomes) will be continued beyond the end of the external support. Considering also potential risks in the context.	☐ ☒ ☒ ☐ ☐	*Very good: Very likely based on evidence* *Good: Likely based on evidence* *Poor: Little likelihood based on evidence* *Bad: Unlikely based on evidence* *Not assessed / Not applicable* [1]	Chapter 7.e – depending on context and targeted scale
11. The extent to which partner organizations are capable to carry on activities. Capacity includes technical, financial capacity, human resources and importance of the activity for the organization.	☐ ☒ ☒ ☐ ☐	*Very good: Strong capacity (also to further develop without support)* *Good: Reliable capacity* *Poor: Little capacity (require further support)* *Bad: Still too weak capacity* *Not assessed / Not applicable* [1]	Chapter 7.e. – depending on context and targeted scale. Additional support would help to achieve a large-scale deployment in the near future

Additional information (if needed): Click here to enter text.
Project: Low Carbon Cement Project (LCC), Phase 2
Assessor: Philippe Fonta, Bernard Mathieu, Andrin Fink
Date: 05.11.2019

[4] Dimensions for consideration are: a) structure (informed policies, laws, corresponding to basic HR obligations; degree of decentralization/multilevel concertation/cooperation); b) good governance in the performance/interaction of responsible actors/institutions (GGov principles: participation, transparency, accountability, equality&non-discrimination, effectiveness & efficiency, rule of law); c) capabilities, behavior, empowerment of actors/institutions for positive change; d) consideration of important global or regional governance dimensions.