MASTER'S COURSE "TOWARDS SUSTAINABLE MATERIALS"

Industrial sustainability initiative case study: Concrete

April, 14. 2025 - EPFL
Christophe Levy, Scientific Director - Holcim Innovation Center

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20 GOLDEN RULES FOR SUSTAINABLE CONSTRUCTION (2010)

PRIORITIZE PASSIVE DESIGN TO REDUCE ENERGY DEMANDS

1. Compact envelope shape
2. Optimized openings & orientation
3. High thermal insulation
4. Optimized air tightness
5. No thermal bridges
6. Green or reflective roofs
7. Solar protections

REDUCE ENERGY DEMANDS WITH EFFECTIVE VENTILATION

8. Natural ventilation (stratification, chimney....)
9. Integrated structure & services
10. Evaporative cooling

INCLUDE PASSIVE THEN ACTIVE RENEWABLE ENERGIES

11. Optimized glazing
12. Reflectors for natural daylight
13. Solar capture on opaque walls
14. Thermal mass
15. Renewable sources of energy

OTHER ASPECTS OF SUSTAINABLE CONSTRUCTION

16. Building flexibility
17. Superior acoustic comfort
18. Efficient water management
19. Reduced material footprint
20. Integrated design

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19. Reduced material footprint ?

Materials represented:
- 10-15% of the total emissions in 2010
- 25-35% in 2030
- 45-60% in 2050

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HOLCIM SUSTAINABLE CONSTRUCTION ACADEMY
A NEW AND AMAZING TRAINING TOOL (OCT. 2024 - SEPT.2026)

HOLCIM SUSTAINABLE CONSTRUCTION ACADEMY

1. Introduction to Sustainable Construction Course
2. Life Cycle Stages of Construction Projects & Products Course
3. Concrete Essentials: Basic Properties of Concrete Course
4. Designing with Concrete Course
5. Low-Carbon Cement and Concrete Course
6. Circular Construction and Concrete Course
7. Sustainable Built Environment: Roundtable Discussion Course
8. Thermal Performance of Concrete Buildings Course
9. The Future of Concrete Construction Course
10. The Future of Regenerative Cities Course

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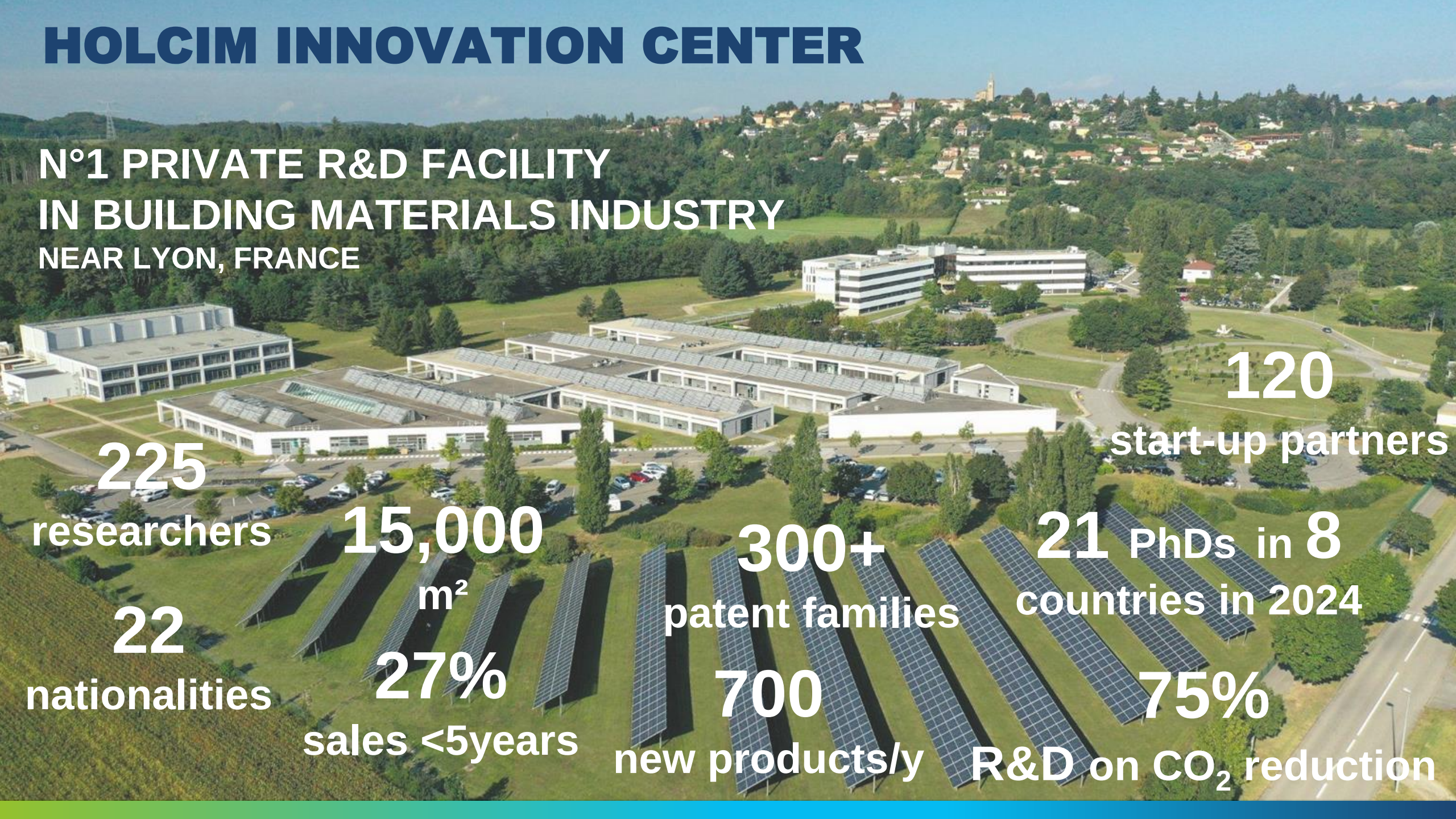


N°1 PRIVATE R&D FACILITY IN BUILDING MATERIALS INDUSTRY

NEAR LYON, FRANCE

225 researchers

15,000 m²

300+ patent families

21 PhDs in **8** countries in 2024

120 start-up partners

22 nationalities

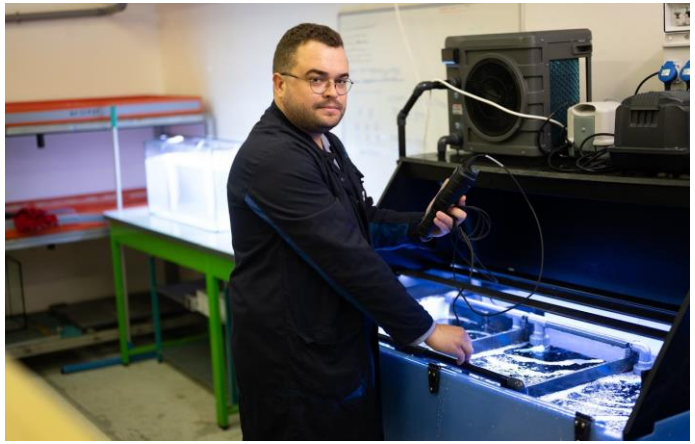
27% sales <5years

700 new products/y

75% R&D on CO_2 reduction

OUR EXPERTISE

BACKED BY 100+ LABORATORIES AND 3000+ EQUIPMENTS



MATERIAL ANALYSIS

- Physical and chemical analysis
- Chemical reverse engineering

CEMENT

- Manufacturing process design
- Hydration chemistry
- Binder formulation

CONCRETE

- Ready-mix and precast mix design
- Concrete rheology
- Admixtures
- Full-scale trials

CONSTRUCTION ENGINEERING

- Engineering
- Jobsite operations
- Modelling
- Mechanics
- Architecture
- Building systems prototypes

DURABILITY

- Microstructure and microscopy
- Service life design and testing
- Life cycle analysis

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R&D PROJECTS TO DRIVE DECARBONIZATION AND CIRCULARITY

GREEN OPERATIONS
Decarbonizing Holcim

BUILDING BETTER WITH LESS
Decarbonizing construction

CIRCULAR CONSTRUCTION
Building new from old

MAKING BUILDINGS SUSTAINABLE
Decarbonizing cities

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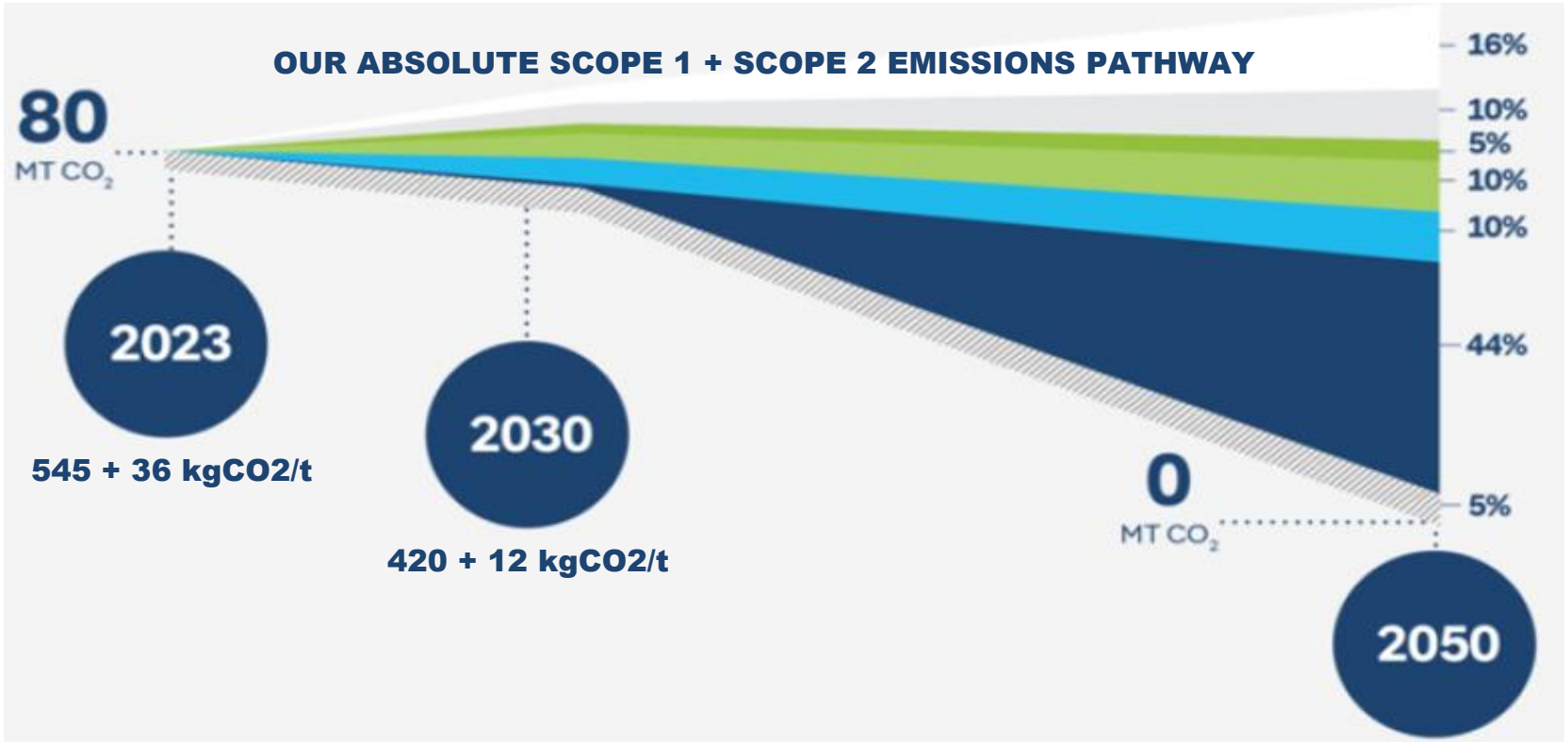
HOLCIM'S PATHWAY TO NET ZERO

THERE IS NO SILVER BULLET

GREEN OPERATIONS



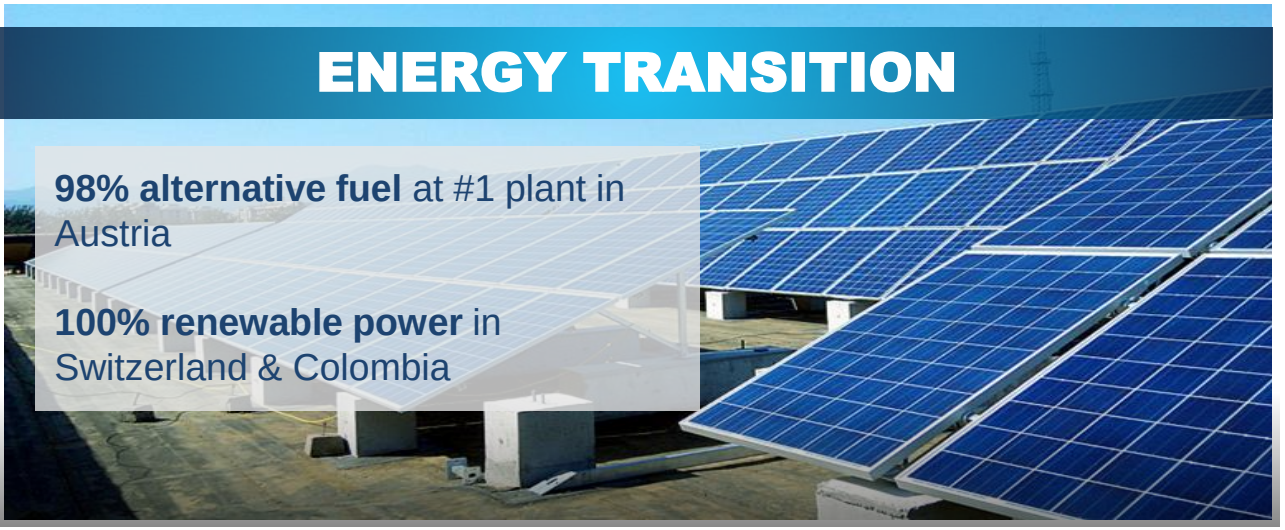
- efficiency gains in design + construction
- efficiency in concrete
- decarbonization of electricity
- less clinker in cement (clinker factor)
- less co_2 in clinker (arm, efficiency)
- ccus, other technologies
- passive recarbonation

47%	25%	2.5%		5%	20%
Raw materials decarbonation Cement production	Fuels combustion Cement production	Energy generation	0.5%	Aggregates and RMX operations	Purchased electricity	Transportation emissions

4 LEVERS TOWARDS NET-ZERO CEMENT

GREEN OPERATIONS

ENERGY TRANSITION



98% alternative fuel at #1 plant in Austria

100% renewable power in Switzerland & Colombia

LOW-CARBON FORMULATION

Separate grinding in 23 plants, 24 to come

Calcined clay in 8 cements, 12 to come

CDM in 5 cements, 15 to come

UPCYCLING CDM

Construction demolition materials (CDM) upcycled as alternative raw materials (ARM) and SCM

15% ARM in average in our cement plants

CCUS

7 EU innovation fund grants & 50 projects worldwide

5 million tons of CO2 captured in 2030

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GREENER FORMULATIONS
CALCINED CLAY & CONSTRUCTION/DEMOLITION MATERIALS

GREEN OPERATIONS

Expanding range of innovative low-emission alternative materials

CALCINED CLAY
8 cements, 12 to come

CDM
10M TONS by 2025

Over 20 alternative materials in our green formulation portfolio

- Waste Limestone
- Steel Slag & Air Cooled Slag
- Road Sludge
- Soil Excavation
- Aluminum/Iron Scrap
- Paper Mill Ash
- Bottom Ash
- Reclaimed Fly Ash
- Blast Furnace Slag
- Fresh Fly Ash
- Pozzolana
- …and more

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DECARBONIZING CONSTRUCTION

BUILDING
BETTER WITH LESS

LOW-CARBON MATERIALS

The world's broadest range of low-carbon concrete and cement

ECOPact ECOPlanet

SMART DESIGN

Using minimum materials for maximum structure efficiency

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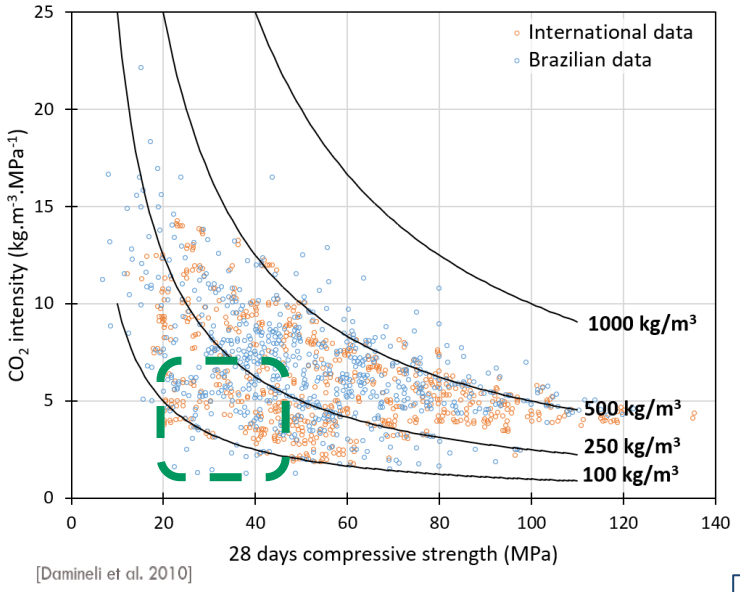
FROM EXISTING ECOPACT (30%) TO ECOPACT NEW GENERATION (7%)
ACTIVATING SEVERAL LOCAL LEVERS TO ADDRESS MASS MARKET

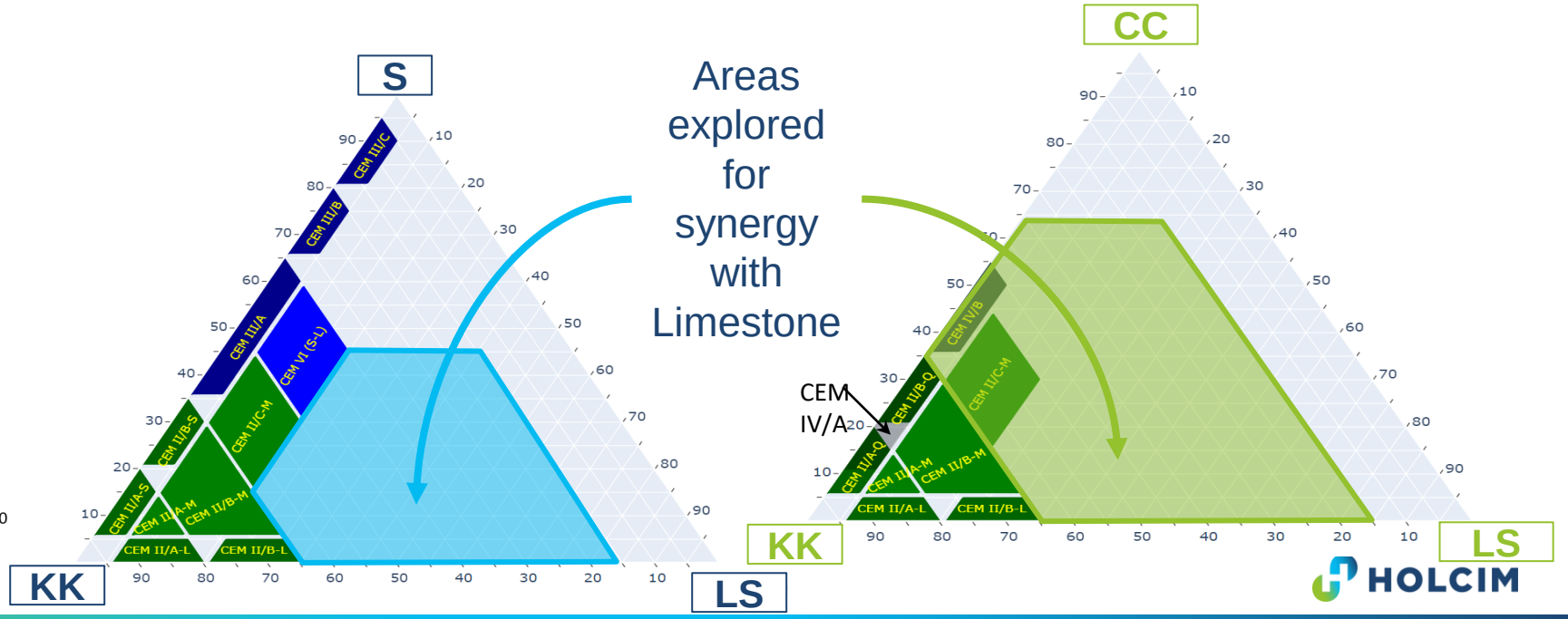
Lever 0 = Day to day optimization (sand/agg quality, industrial tools, digitalization, etc…)

Lever 1: Binder
With slag, fly ash, calcined clays, reclaimed ash, concrete fines…

Lever 2: High filler %
Sober use of cement, performance-based

Lever 3 = Aggregates
Agg packing optimisation, Carbonated RCA as sink





SMART DESIGN
FROM 3D PRINTING TO PREFAB & MODULAR

BUILDING
BETTER WITH LESS

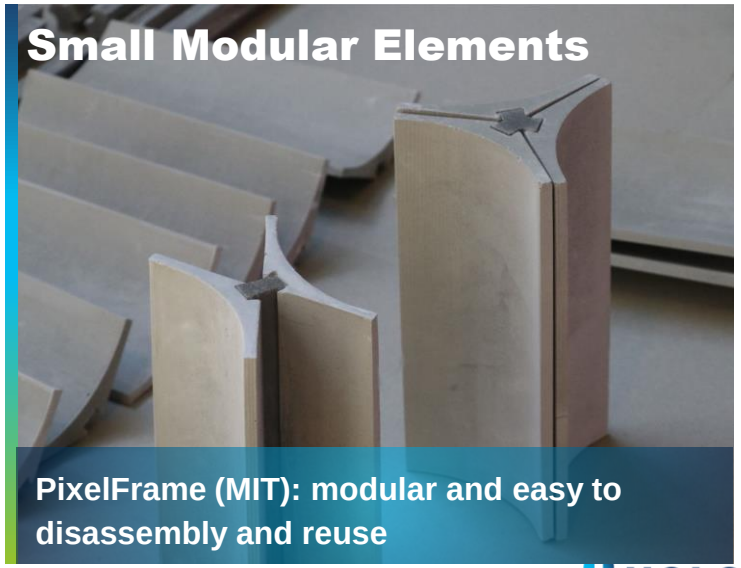
High Performance Concrete for thin design
MIRO office complex, Romania

3D-printed affordable housing project
Mvule Gardens, Kenya

Rippman Flooring System (ETHZ):
Crea Tower Project, Switzerland

Uniting aesthetics and durability
Nike Store, Miami, USA

Up to 80% less materials, 75% less CO2.
Cradle to cradle certified solution



PixelFrame (MIT): modular and easy to disassembly and reuse

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DECARBONIZING CITIES

MAKING BUILDINGS SUSTAINABLE

INSULATING FOAM FOR ENERGY EFFICIENCY

COOL AND GREEN ROOFS

LIVING WALLS TO ENHANCE BIODIVERSITY

PERMEABLE CONCRETE TO REDUCE URBAN HEAT BY UP TO 6°C

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UPCYCLING CDM ACROSS ALL PRODUCT LINES

CIRCULAR CONSTRUCTION

CDM FOR RECYCLED AGGREGATES

New technologies to produce quasi-virgin aggregates at 2 plants, 4 to come

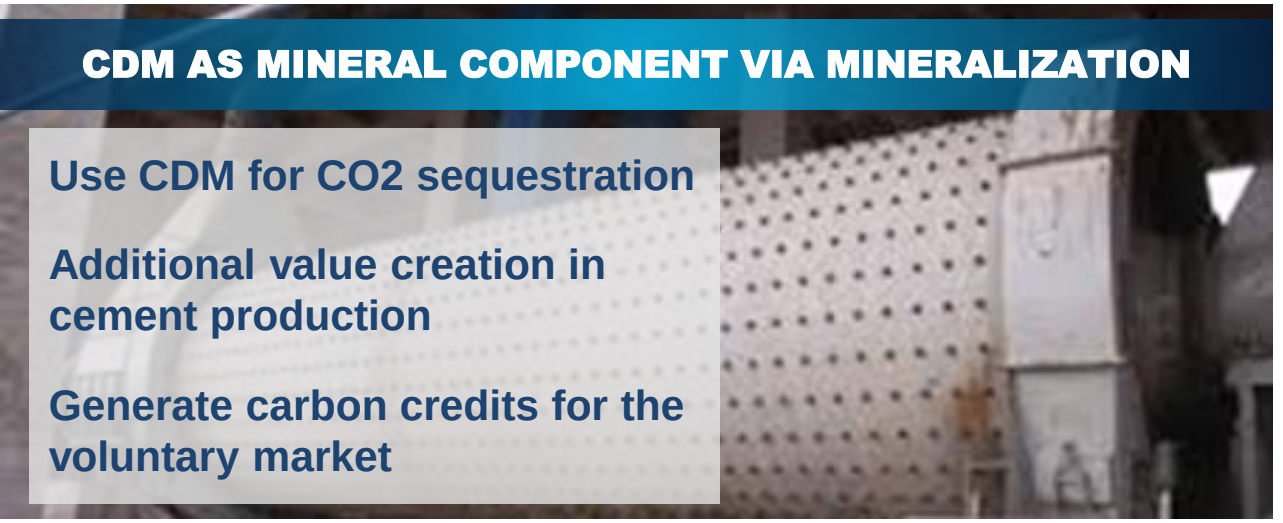
Accelerate market adoption of recycled aggregates in RMX

CDM AS ALTERNATIVE RAW MATERIALS

Removal of silica with the CDM coarse fraction

Lower clinker CO_2 footprint

CDM AS MINERAL COMPONENT VIA MINERALIZATION



Use CDM for CO_2 sequestration

Additional value creation in cement production

Generate carbon credits for the voluntary market

CDM AS MINERAL COMPONENT VIA THERMAL ACTIVATION

Optimal CDM performance as new mineral component

Optimal value creation in cement production

Lowest clinker CO_2 footprint

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A WORLD FIRST: 100% RECYCLED CONCRETE

CIRCULAR CONSTRUCTION

GENNEVILLIERS,
PARIS AREA, FRANCE - 2024

1,600 m^3

FULLY RECYCLED CONCRETE
(C25/30 XC4/XF1 DMAX14 S4 CL0.4)

220 units

INCLUDING 70 SOCIAL HOUSING, ACROSS 2 RESIDENTIAL BUILDINGS (G+5 & G+6)

195 kgCO_2/m^3

OR 15% LESS THAN STANDARD CONCRETE

6,000+ tons

NATURAL RESOURCES SAVED

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FULLY RECYCLED CONCRETE COMPONENTS

CIRCULAR CONSTRUCTION

RECYCLED CEMENT

CEM III/A 42.5 N CE - EN 197-1 made with another world first:

- 50% fully recycled clinker made in a cement plant with 100% local industrial co-products
- 45% GGBS
- 5% Anhydrite

Same chemical and mineralogical composition than ordinary clinker made with virgin quarried limestone and clay

RECYCLED AGGREGATES

Made exclusively from recycled construction demolition materials:

- Recycled sand 0/4
- Recycled coarse aggregate 4/12
- Average CDM quality:
  - . Rcu >95% (concrete & gravel content)
  - . sand: d=2.06 & WAbs=8.3%
  - . coarse agg.: d=2.26 & WAbs=6.6%
  - . too much old paste attached on agg.

RECYCLED WATER

Using process wastewater and rainwater, collected at the Ready-Mix plant

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FULLY RECYCLED CONCRETE MIX DESIGN & CHARACTERISTICS

MIX DESIGN

C25/30 XC4/XF1 Dmax14 S4 Cl0.4

Component	Designation	Quantity (kg/m3)
Cement	CEM III/A 42.5 N CE (specific batch)	335
Aggregates	RC sand 0/4	740
	RC gravel 4/14	530
Addition	Fly ash	160
Water	Recycled water	180
Admixtures	Superplasticizer	2
	Accelerator	4,5
	Polypropylene fibres	2
	Water to cement ratio	*0.537*

Performance Based approach (durability and structural)

CO2 footprint: 195kg CO2 eq/m3

FRESH PROPERTIES

Characteristics	Time of measurement after concrete mixing			
	5’	30’	60’	90’
Slump value (mm)	225	215	195	175
Density (kg/m3)		2110		
Air content (%)		2.3		

HARDENED PROPERTIES

Characteristics	Time of measurement			
	1d	7d	28d	90d
Compression (MPa)	4	23	36	41
Splitting (MPa)			3.1	
Pull-out test (MPa)			11 (vs ref. 18)	
Shrinkage (mm/m)	0	-0.256	-0.664	-0.925
E Modulus (GPa)			21 (vs ref. 30)	
Resistivity (Ohm.m)				195
Acc. Carbonation (mm/y^0.5)				2.0

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COULD WE GO FURTHER?

GREEN OPERATIONS + CIRCULAR CONSTRUCTION

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CARBON SINK

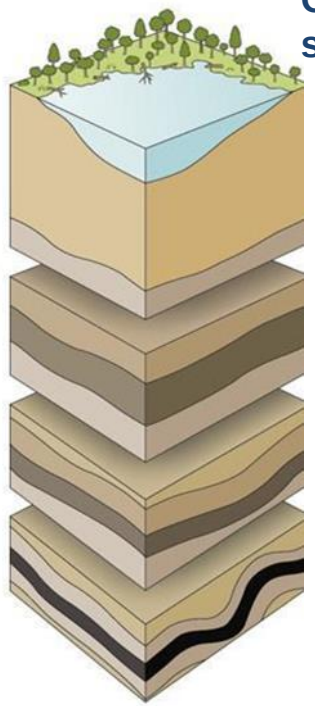
BIOCHAR - ACKNOWLEDGED BY IPCC AS A CARBON DIOXIDE REMOVAL

WHAT IF ORGANIC WASTE COULD TRAP CO2?
(agriculture waste, tree prunings, municipal waste, sewage sludge…)

ipcc
INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

ORGANIC CARBON STORAGE PATHWAY

Atmospheric CO2 is naturally sequestered and transferred into permanent storage via geological processes (million of years)



Organic carbon evolution stage (million of years)

Bacterial degradation

Thermal degradation

Metamorphism

Graphite

BIOCHAR MANUFACTURING

Mimics process by which fossil carbon is formed over geological timescales (but in hours)

BIOMASS

PYROLYSIS (1-2 hours)

BIOCHAR

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A WINNING COMBINATION

CONCRETE => STORAGE MEDIUM & BIOCHAR => NET ZERO CONCRETE

Biochar RMX Concrete Carbon Sink

50 kg of biochar per m^3 enables:

up to -150* kg CO_{2eq}

Technically compatible

- ✓ Fresh and Mechanical properties of concrete maintained
- ✓ Limited adjustment and effect on concrete color
- ✓ Dosage up to 100 kg/m3

Net zero target

- ✓ Get Biochar negative carbon footprint included in the concrete EPD (A1-A3) up to net zero
- ✓ Testing Biochar concrete from existing suppliers at different dosages to develop internal know-how

First Proofs of concept

- ✓ POC realized in 2024 in many Holcim countries
- ✓ Gathering customer perception, expectations, ideas
- ✓ Commercial development to come

* Refers to the production impacts (A1-A3 stages of an EPD) assuming a biochar containing 90%C

CONCLUSION

We will be successful in reaching the Double Zero Quest if:

- CONSTRUCTION INDUSTRY HAVE AN HOLISTIC APPROACH, TAKE RISKS AND MOVE FAST

- USEFUL KNOWLEDGE IS SHARED AND TRANSFERRED

- GOVERNMENTS OFFER ADEQUATE INCENTIVES, BASED ON LCA-BASED CO2/M², BUT NOT ON TYPE OF MATERIAL

- ALL STAKEHOLDERS COLLABORATE TOGETHER

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