3D printing in Kenya

We want to disrupt construction with a new way of building affordable and sustainable buildings in Kenya

Presentation to AAK

June 2021

14 TREES
Building better lives.

14 Trees Introduction : dedicated to taking innovation from the lab to the field

A lot of solutions to build more affordable housing and schools exist, but they remain in the labs of large companies and start ups.

Our mission is to take construction innovations from labs to the field, test them, optimize them, and take them to scale.

So that more African families can live in a decent and affordable house and every child can go to school.

Our operations

Malawi Kenya

Switzerland (head office)

Our shareholders

LafargeHolcim — World leader in building materials & solutions

CDC — UK Government's Impact Investor

Our impacts

9500+ Trees saved

~100 direct jobs created in Africa

1500+ indirect

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14Trees: details on our organization

- **14Trees Holding entity is incorporated in Switzerland – LafargeHolcim owns 51% of it, and CDC, the UK impact investor owns 49%**
  - 14Trees Holding fully owns 2 subsidiaries: 14Trees Malawi and 14Trees Kenya
  - 14Trees has its own governance with a Board of Directors where LH and CDC are represented
  - 14Trees accesses LafargeHolcim R&D center, the largest research center in the construction industry, based out of Lyon, France

- **14Trees is a for profit company with a mission**: we are there to solve the issue of access to housing and social infrastructures in a way that contributes to preserving the environment

- **14Trees has its own teams with competences ranging from architecture to quantity surveying to construction execution**, with a focus on 3D printing– cf. appendix

14 Trees Introduction: Project team

Management Team

François Perrot – Managing Director

- ✓ 15 Years on Affordable Housing business in Developing Countries
- ✓ Based in CH with relocation to MEA soon

Colm Halley – Kenya General Manager

- ✓ Ex Fosroc Kenya CEO
- ✓ 20 Years in Construction and NGO field, of which 12 in Kenya. Based in Kenya

Didier Chayramy – 3D Operations

- ✓ Over 15 years of experience in operations management in Africa
- ✓ Mobile across Africa

Design office

Denis Chek – Regional Construction Manager

- ✓ 10 Years in construction management for large projects in East Africa. Qualified QS, EDGE certified, PMP®
- ✓ Based in Kenya

Thandizo Kachiza – Architect

- ✓ Qualified Architect. Previously with Mass Design in Rwanda, leading African architecture firm
- ✓ Based in Malawi

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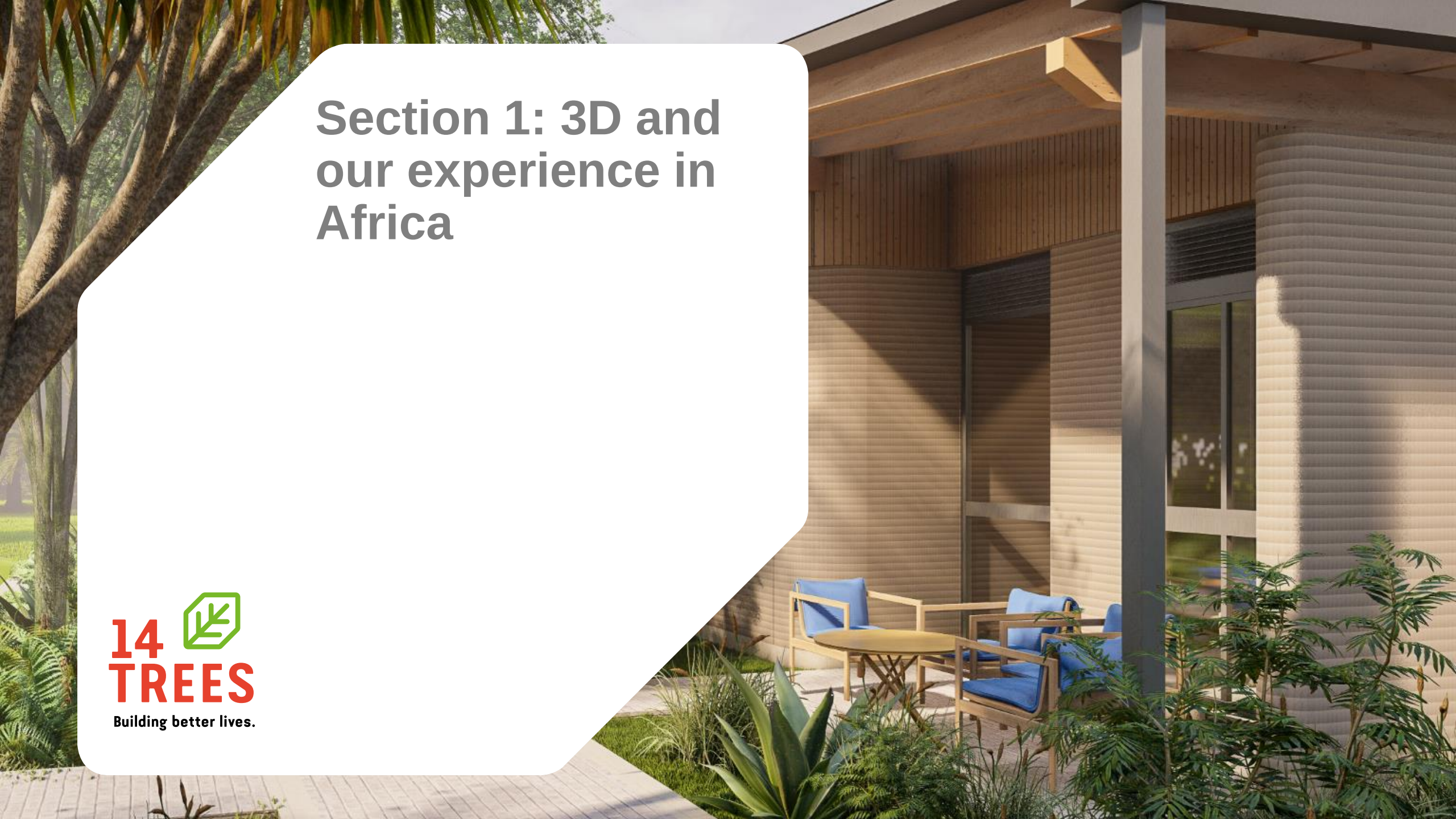
Section 1: 3D and our experience in Africa



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What is construction 3D printing?

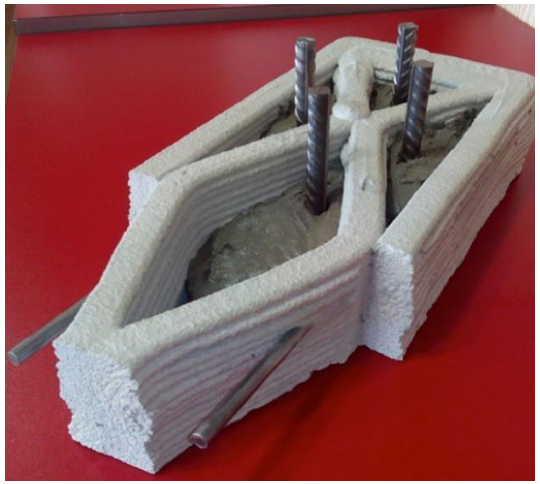
Construction 3D Printing

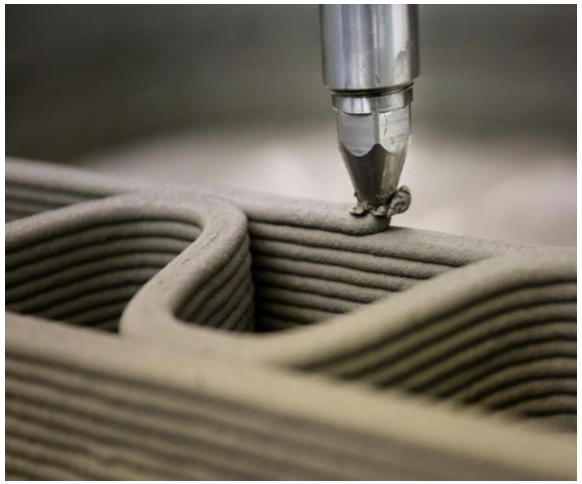
Molding of a structure by placing volumes of material in sequential layers on top of each other from the ground up. The material is pushed through a nozzle which regulates flow and is guided by computer controlled positioning process.

Benefits of 3D printing

Fast and Reliable

The sub and super structure can be built within a few days compared to several weeks from conventional methods. The machine can work day & night. The quality of the buildings built can be monitored more closely and shortcuts in the construction field are reduced.





Cost effective and Enhanced Sustainability

Increased efficiencies throughout the construction process translate to using less materials (by reducing the width of the walls). In addition, the project will use natural, sustainable and recyclable materials (earth-based mortar, broken bricks, etc).

Unique Design

3D printing allows to build structures that cannot be achieved by humans. Not only are 3D-printed buildings unique in design, but they can also be more resilient to natural disasters thanks to the shape of the building.

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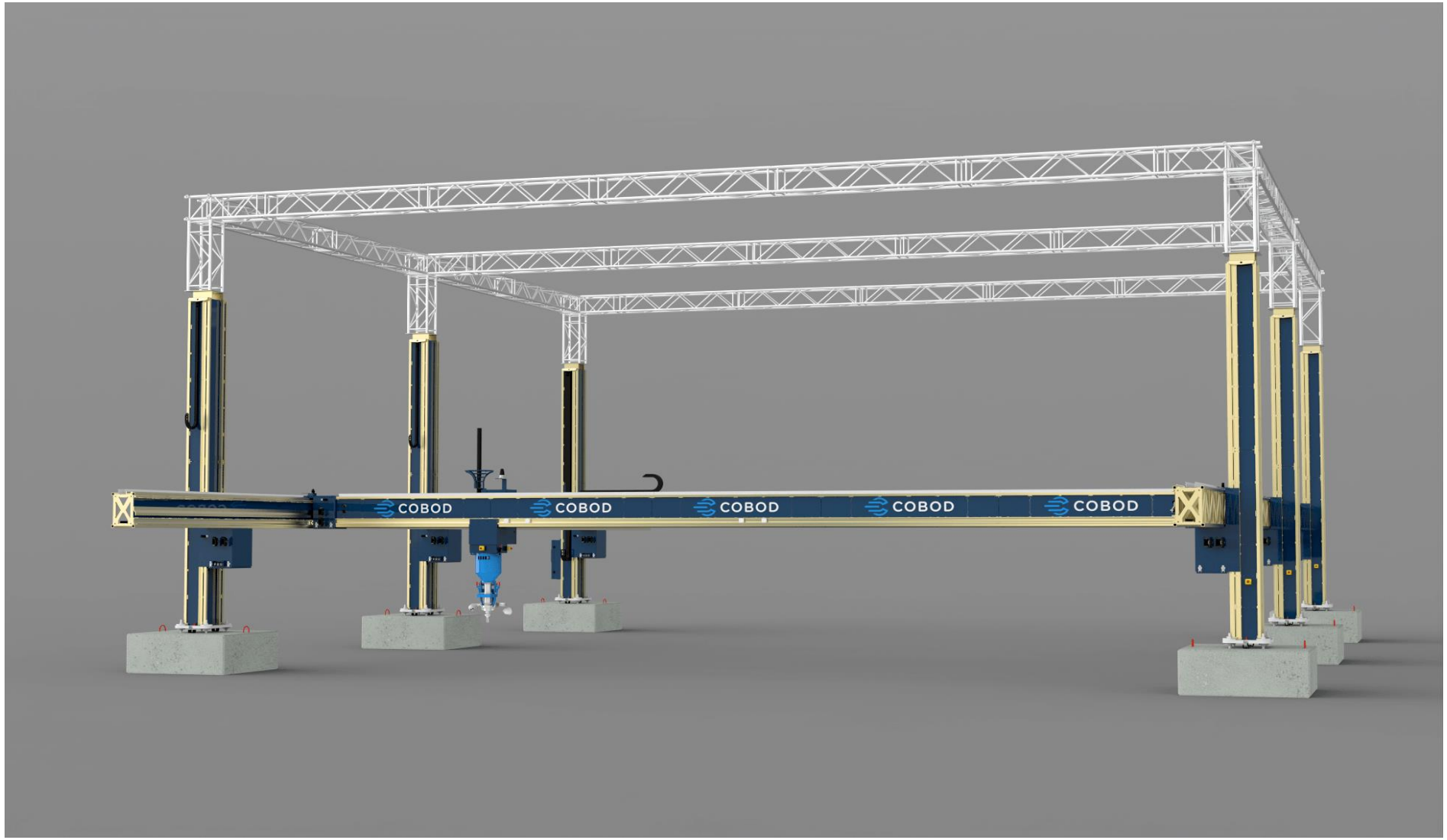
COBOD BOD 2 – 5 X 8 X 2 PRINTER

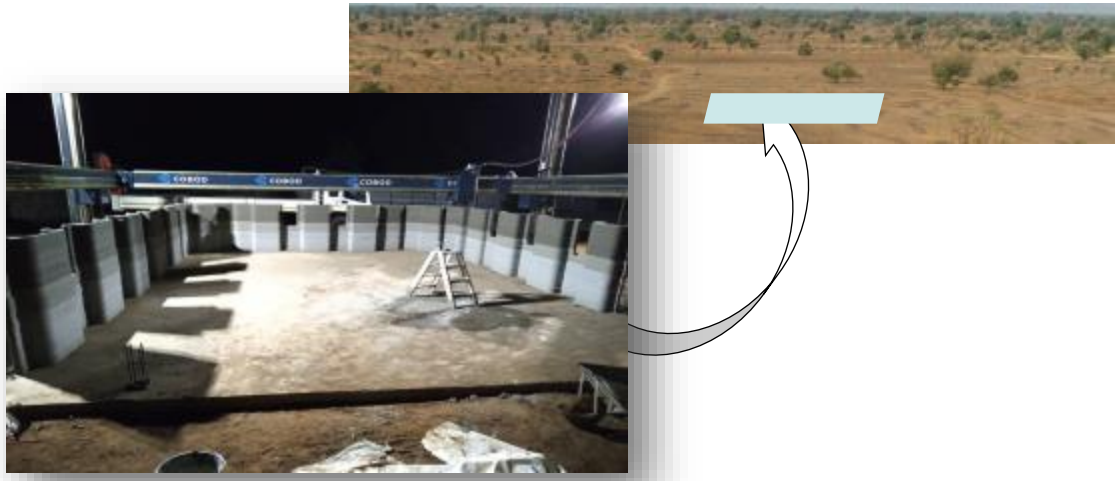


Our experience in 3D printing : Existing Pilots Projects in Malawi

We printed a 36 sq.m house in 12 hours in Malawi

- ✓ Double layer wall with metallic binders and stiffeners under the windows
- ✓ Night printing to enjoy lower temperatures
- ✓ 14 tons of 3D mortar

We also printed a 56 sq.m. school in rural Malawi



- ✓ Single layer wall
- ✓ No electricity & water on site
- ✓ Extreme weather conditions: strong wind, night rains, temperature ~40°c

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3D printing buildings does work

- The first 3d printed home in East and Central Africa was printed in Malawi in late 2020.

3D printing buildings does work

3D Printed

- The first 3d printed classroom block was printed in Malawi in late 2020. On the photo is the 1st classroom 3D printed in Africa by 14 Trees

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Section 2: Building the Worlds 1st 3D Constructed School

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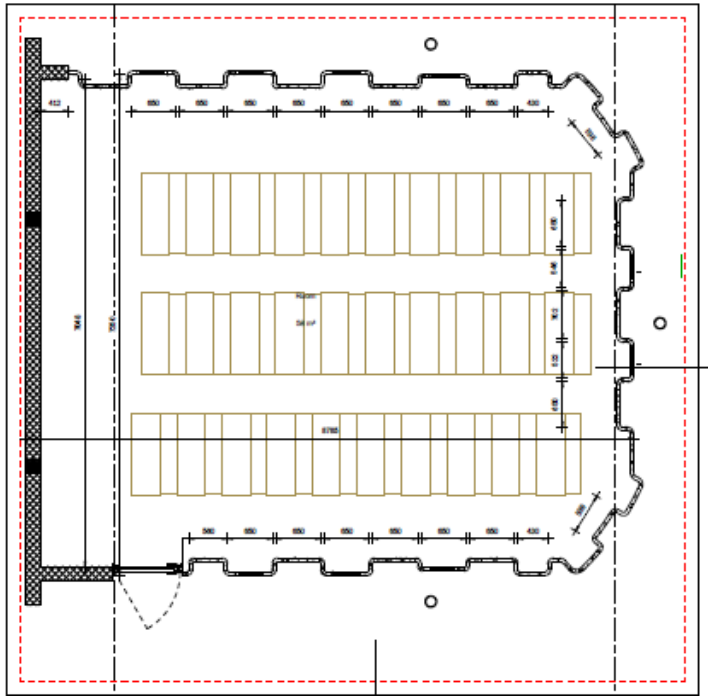
Sequence of 3d Printing Construction
3d Printing Pilot Rural Malawi

3D Printed

- **3D Printed Pilot In Malawi - Salima was created with the following design criteria:**

Main characteristics

- 3D-Printed Walls (Single Kernel)
- Gross floor area – 58 sm
- Slab area 100 sm
- Thickness of walls 5 cm
- Plaster and paint to external walls
- Paint to external walls
- Steel frame structure



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Sequence of 3d Printing Construction

3D Printed

- Excavations for raft foundation – 1 day
- Setting out – 1 day
- Slab preparation work – 2 days
- Casting of concrete slab – 1 day
- Curing – 3 days (use of accelerating concrete admixtures)

- 3d printing the walls – 2 days (night time printing)

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Sequence of 3d Printing Construction

3D Printed

- Fabrication of steel members (to start in conjunction with mobilization of the contractor to site) – 10 days
- Erection of steel columns– 1 day
- Erection of roof frame – 2 days
- Installation of doors and windows – 2 days

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Sequence of 3d Printing Construction

3D Printed

- Roof covering– 2 days
- Vent block installation – 1 day
- Eaves finishing – 2 days
- Paint to internal and external walls– 2 days
- Clearing of site debris – 1 day

Total number of days to build 56sm classroom 23 days

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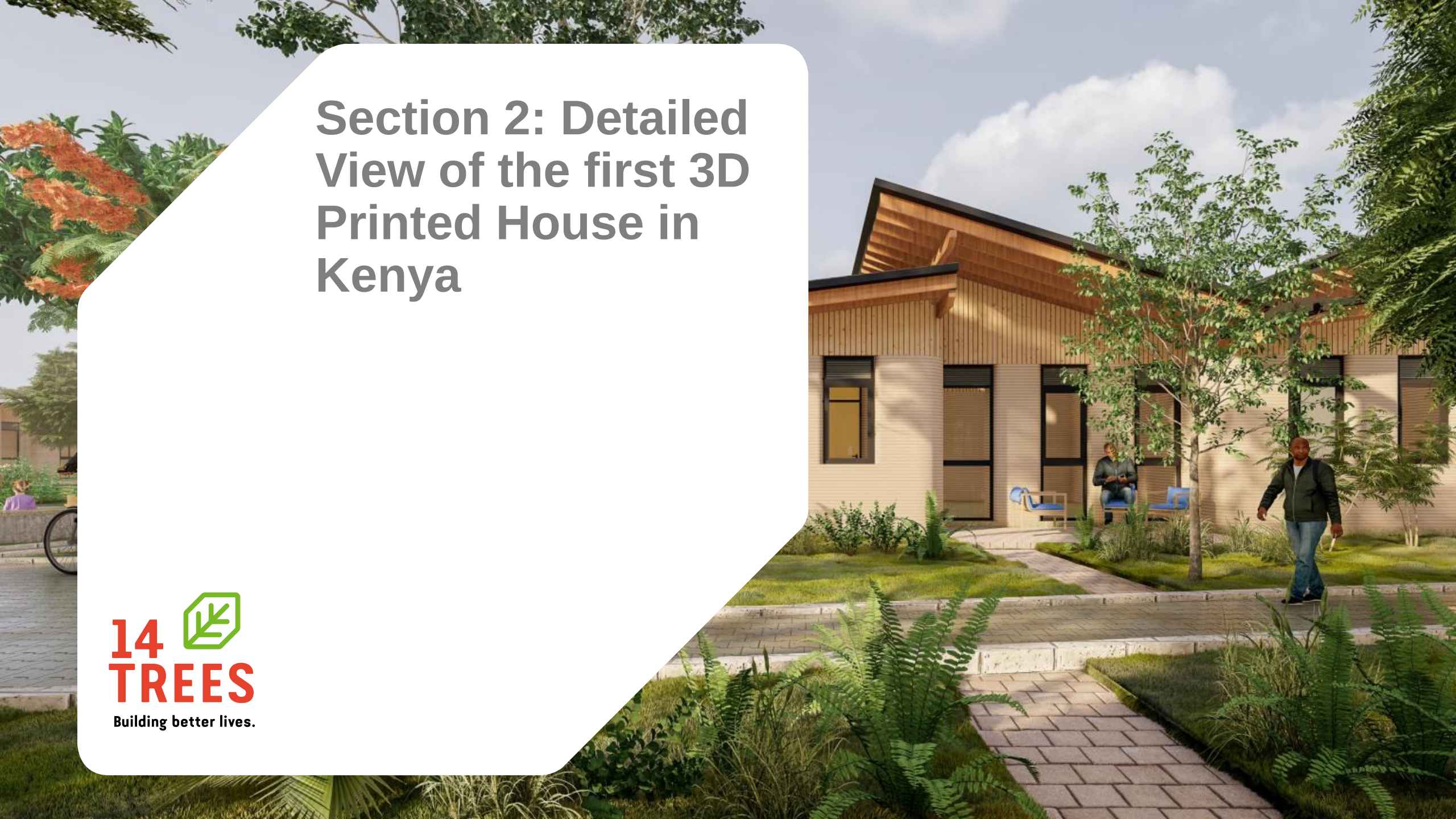
Section 2: Detailed View of the first 3D Printed House in Kenya



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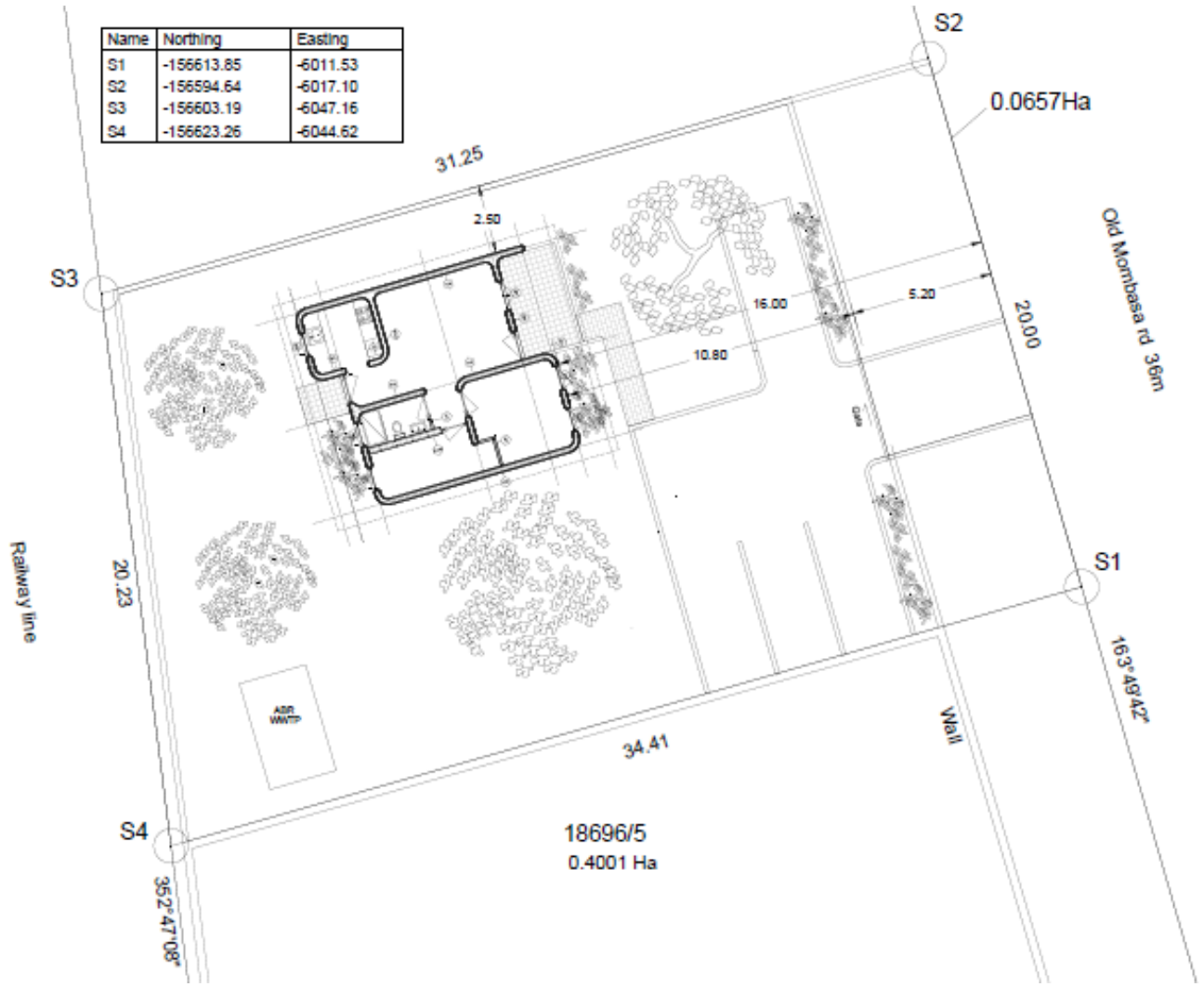
SUMMARY

- Site layout
- 3D Design
- Construction Phasing and Planning
- 3d Printing budget
- 3d Pricing assumptions

Site Layout



Site - 0.166 acres

Gross Floor Area – 56sm

2 bedroom bungalow and associated external works

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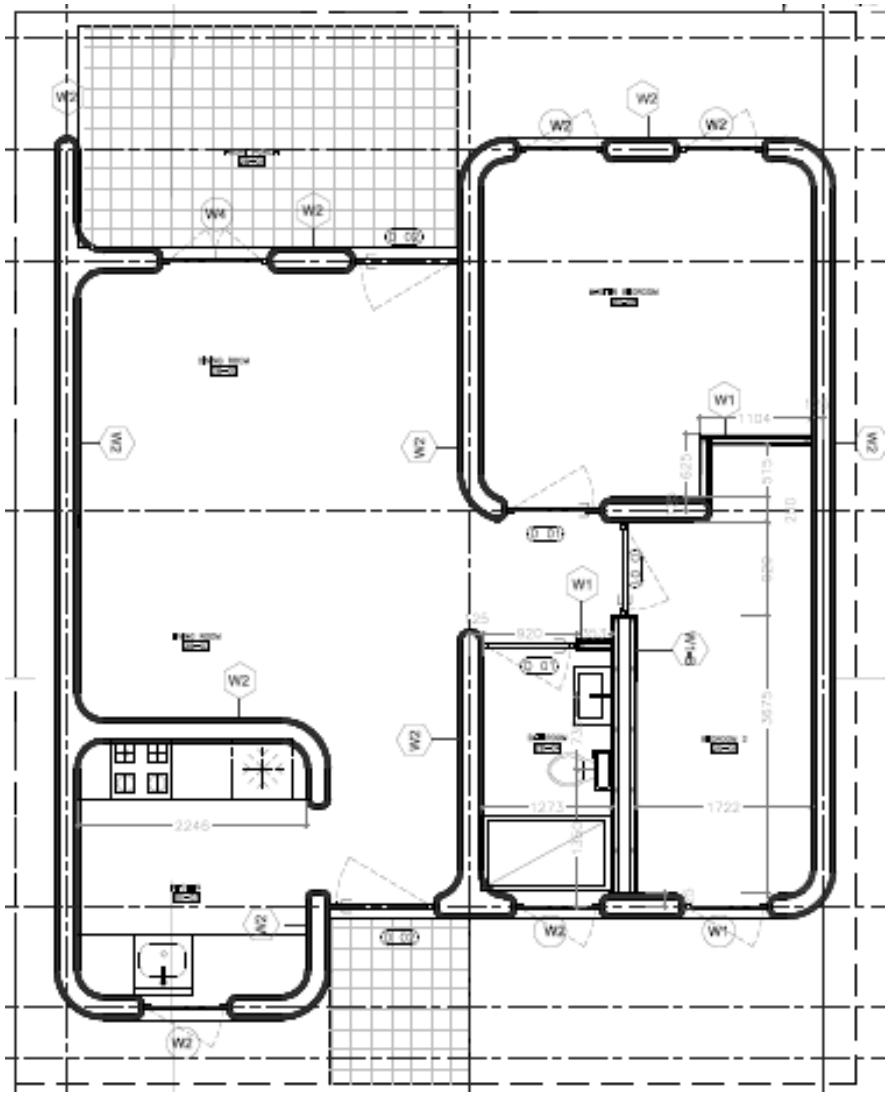
3D Unit Plans

3D Printed



- Two Bedroom Bungalow
- Double layered 3D-Printed Walls and piers
- Gross floor area – 56 sm
- Slab area 330 sm
- Thickness of walls 5 cm +12cm + 5cm = 22cm

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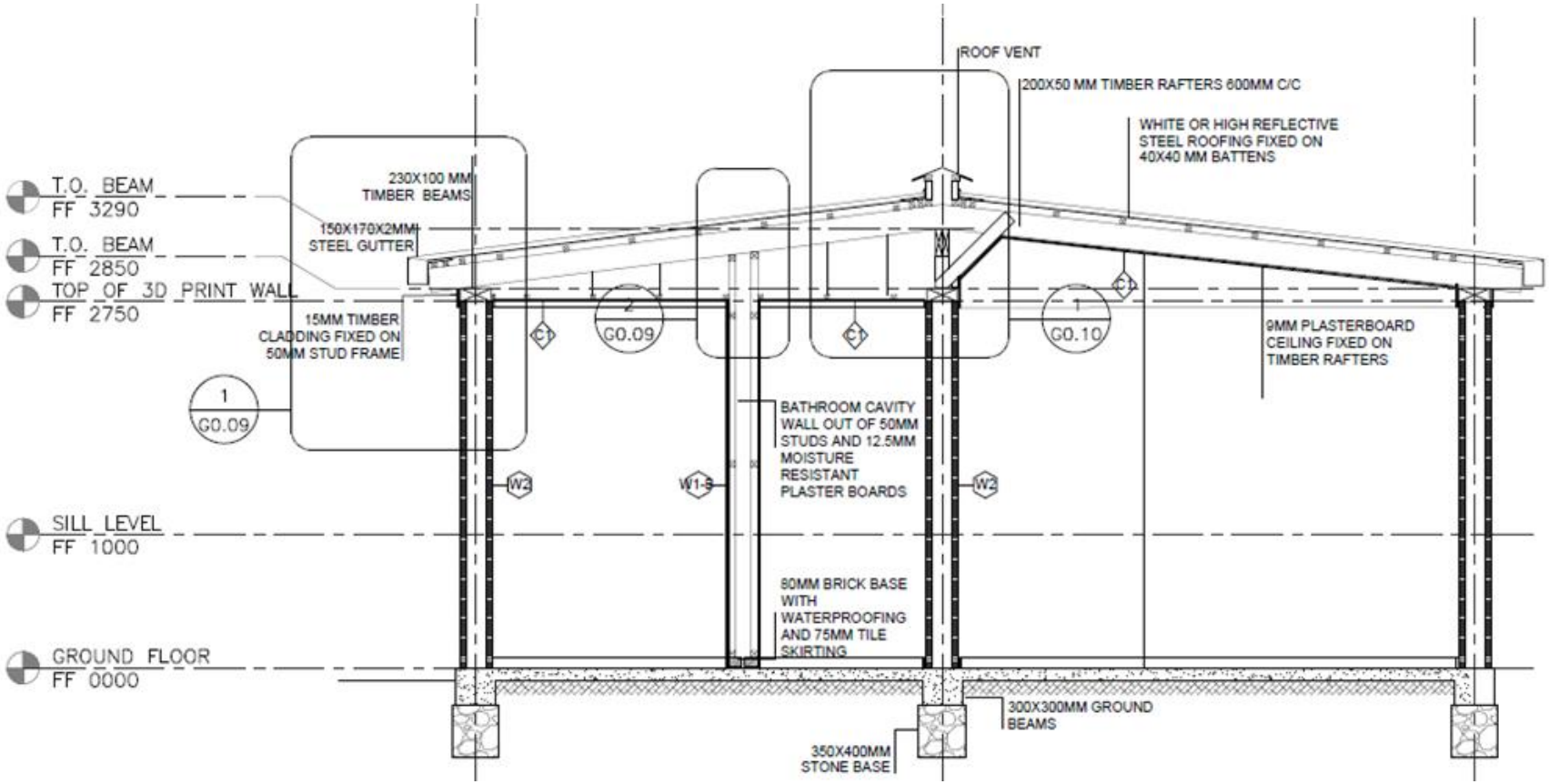
3D Unit Plans

3D Printed



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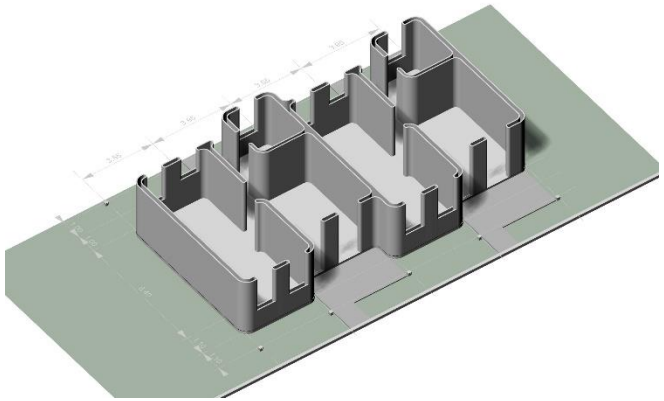
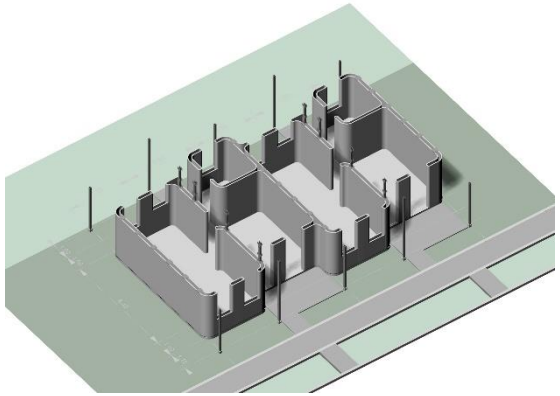
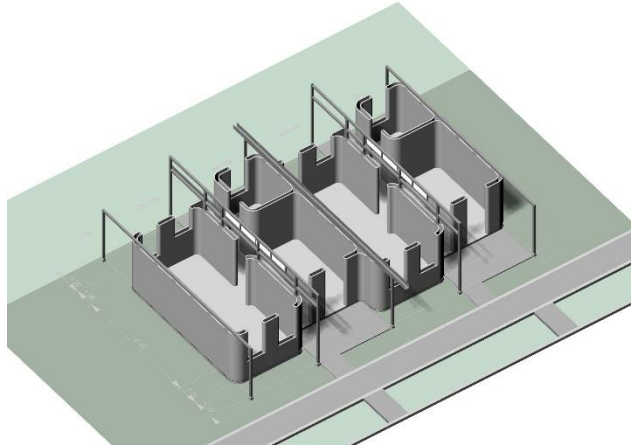
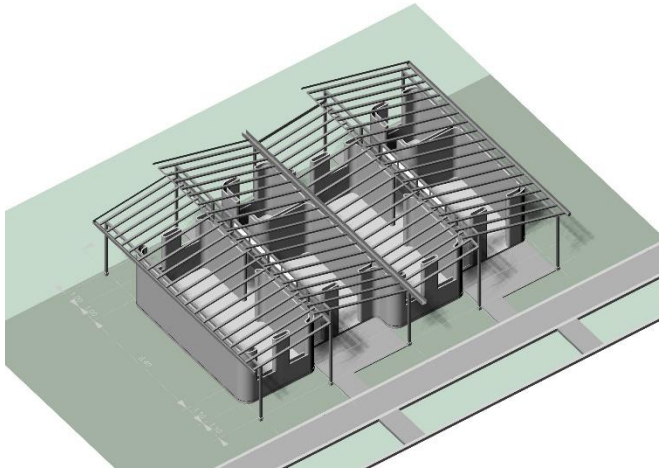
Construction of semi detached 2 bedroom units

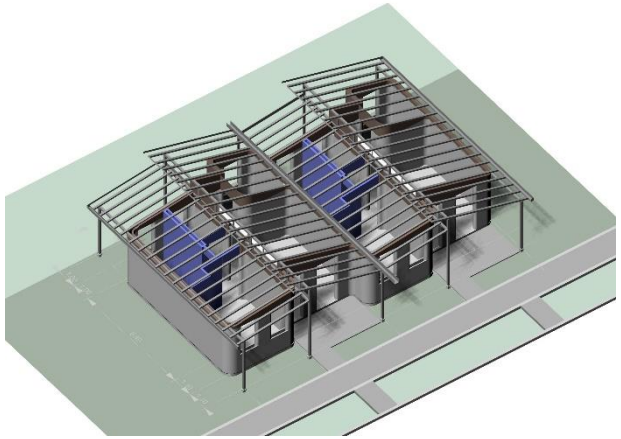
3D Printed

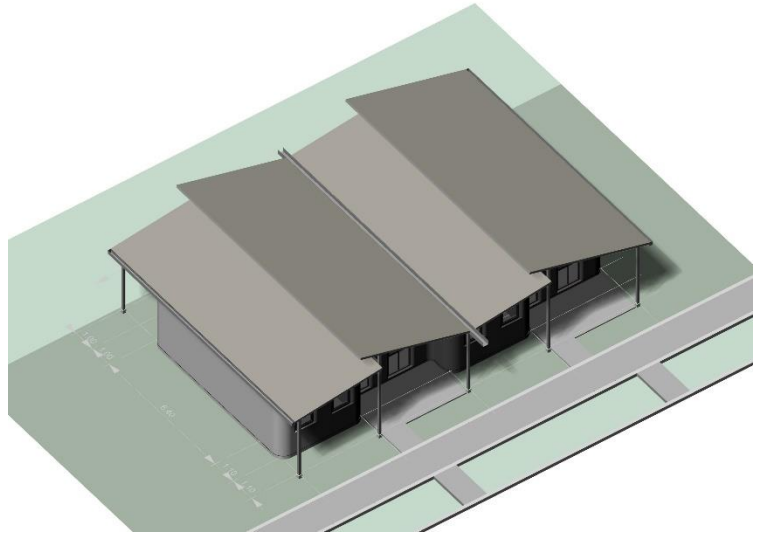












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Construction Costs and Project Budget
Cost comparison

		2 bedroom Bungalow	3D Printed Homes 2 bedroom Bungalow	3D Printed Homes 2 bedroom Bungalow. Kilifi
	Description	**Conventional**	**Pilot 1 Aug 2021**	**Projected for Commercial rollout November 2021**
	Gross area	56 sqm	56 sqm	56 sqm
	Walls	Machine Cut (200 mm thick)	Double wall (180 mm thick)	Double wall (180 mm thick)
	Wall height	2.4 m	2.6m	2.6m
	Foundations	Strip Foundations	Masonary Base, Concrete slab	Masonary Base, Rammed Earth Slab
	Roof	Structural timber finished with prepainted corrugated iron sheets	Structural timber finished with prepainted corrugated iron sheets	Structural timber finished with prepainted corrugated iron sheets
	Finishing	Plaster and paint, ceramic tiles,gypsum ceilings	Paint, ceramic tiles and gypsum ceilings	Paint, ceramic tiles and gypsum ceilings
COST TO BUILD 1 HOUSE		**1,960,000**	**3,001,706**	**1,693,163**
COST PER SM BEFORE INCLUDING 3D PRINTING RELATED COSTS		**35,000**	**321,459**	**30,235**
3D PRINTING RELATED COSTS			**15,000,000**	**144,231**
COST TO BUILD 1 HOUSE		**1,960,000**	**18,001,706**	**1,837,394**
COST PER SM INCLUDING 3D PRINTING RELATED COSTS		**35,000**	**321,459**	**32,811**

3D PRINTING RELATED COSTS: INCLUDE THE TEMPORARY IMPORTATION OF THE 3D PRINTER, IMPORTATION OF THE 3D PRINTING MOTAR REQUIRED FOR THE WALLS, 3D PRINTING OPERATORS AND EXPERT SERVICES.

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Roadmap towards 3D Affordability

- While the 3D printing enables to achieve cost savings on the walls, this decrease is mitigated by the premium spent on building a roof decorrelated from the walls so that it won't collapse and provide a better resilience to disaster

- There are however massive opportunities to bring down the costs. 14 Trees has developed a 3D Construction Affordability Roadmap and have identified key levers that will be implemented over the next 12-24 months that will significantly lower cost of 3d printing highlighted in the previous slide ;

1. 3d Printing Mortar – By having enough pipeline projects in the country the 3d mortar can be locally manufactured thus reducing the need to import the ink from Spain. 14 Trees is also carrying out various tests to reduce the cement quantity in the Ink. These will have a significant impact on the cost of construction
2. Capex and mobility – By investing in a printing machine in Kenya for Kenya as well as the necessary transportation vehicles required to mobilize print and demobilize on site the cost of the 3d printing services can significantly reduce
3. Local Team – By transferring the 3d printing knowledge to locals and building capacity within the region we will eliminate the need of having Expert professionals coming in to do the 3d Printing.
4. Volumes – By having several blocks in one location the cost of mobilization and demobilization would be reduced as it would be shared by the multiple blocks.
5. Evolution of structural design and material – By carrying out a series of tests on material strength and structural designs, we believe G+1 designs, use of 3D for foundations and roof design improvements can provide further reduction in construction costs

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3D printed buildings reduce CO2 by up to 70% vs conventional methods

Comments

- Methodology of this Life Cycle Analysis in Appendix
- Results are obtained for 3D printed houses – no significant variation expected for 3D schools

Summary of results

Results show that the 3D printed building has lower Global Warming Potential impacts compared to these optimum scenarios.

3D vs burnt bricks: -70% CO2

3D vs SSB: - 8% CO2

House components	Baseline (burnt brick)	Baseline (VSBK brick)	Baseline (SSB)	3D
Malawi house CO2 tons	**30,065.56**	**15,710.80**	**10,162.68**	**9,380.50**
Common materials - Floor finishes	290.31	290.31	290.31	290.31
Common materials - Roof finish	484.29	484.29	484.29	484.29
Common materials - Wall finishes	41.56	41.56	41.56	41.56
Common materials - Windows and doors	720.54	720.54	720.54	720.54
External walls	14,710.22	5,945.38	2,223.08	2,019.30
Frame (roof)	1,727.10	1,727.10	1,727.10	2,212.06
Internal walls	2,523.72	1,184.20	875.66	1,209.66
Substructure	9,567.82	5,317.42	3,800.14	2,402.80

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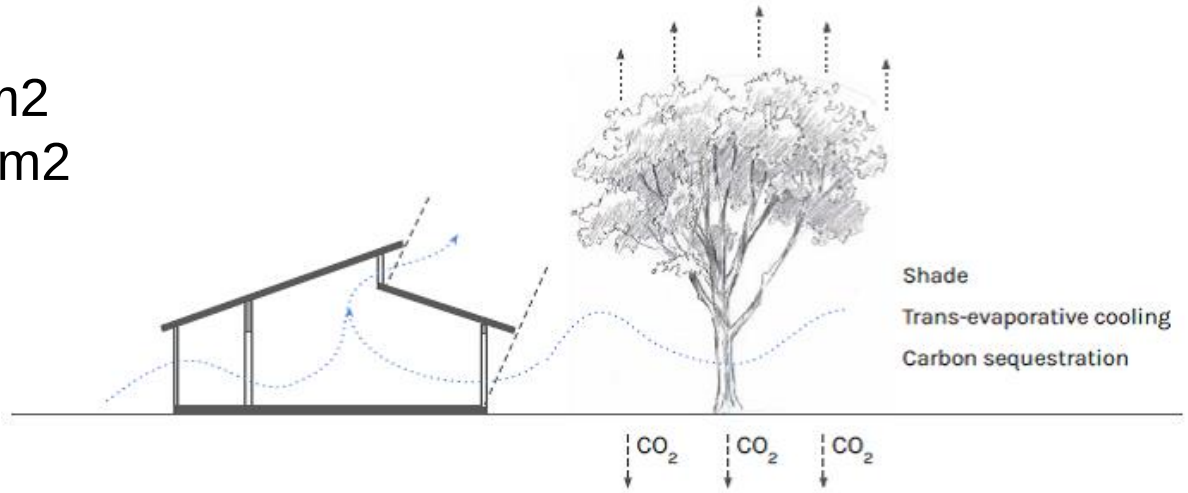
One Tree, One House Strategy to help achieve carbon neutral project

Embodied carbon: 70% below global average
Cradle to gate
Structure only: 128 kgCO2e/m2
Whole building: 214 kgCO2e/m2

Highlights
✓ Material efficient walls
✓ Timber roof
✓ Limited finishes

Estimated reduction of 21 kgCO2e/m2 if reinforced concrete Ground Bearing Slab is replaced with Rammed earth slab, bringing it at 75% below global average.



One House One Tree

Note: More information on project emissions and sequestration strategy within appendices

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