3D Printing Technology for Real Estate Report

James Liao

MHG Marto HG Digital Asset Group

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Overview of 3D Printing Technology

Overview of 3D Printing Technology

- 3D printing technology is a manufacturing process of making three-dimensional solid objects based on a self-designed digital mode. The materials of 3D printing process are usually recyclable

  → **Approach environmental sustainability**

- The creation of a 3D printed object is achieved using additive processes, which is opposite with the traditional manufacturing process of cutting the material

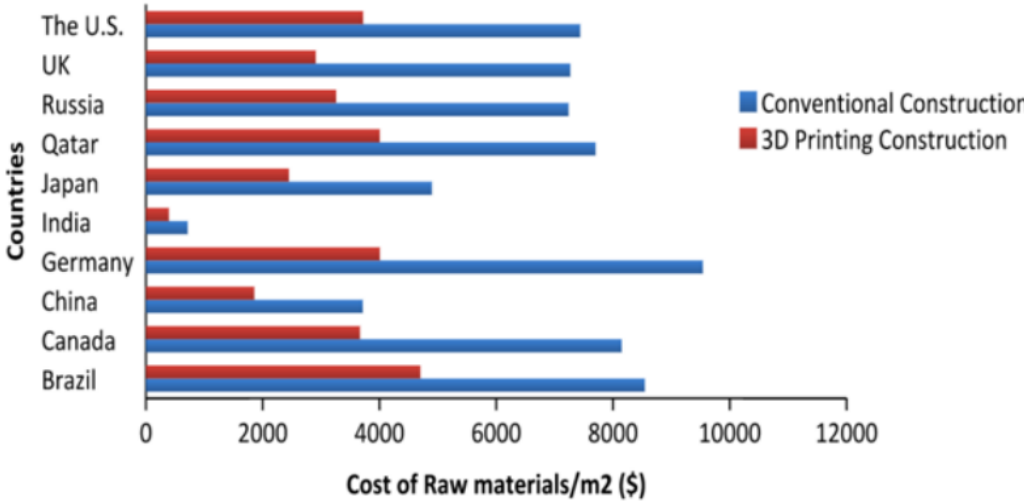
  → **Reduce manufacturing waste**

Overview of 3D Printing Technology

Main benefits of 3D printing techniques:

- Less labor-intensive
- Product design is freed
- Product is more customizable
- Less waste
- Lower cost.

Construction Materials Cost



Source: International Construction Cost Survey

3D Printing in Construction History

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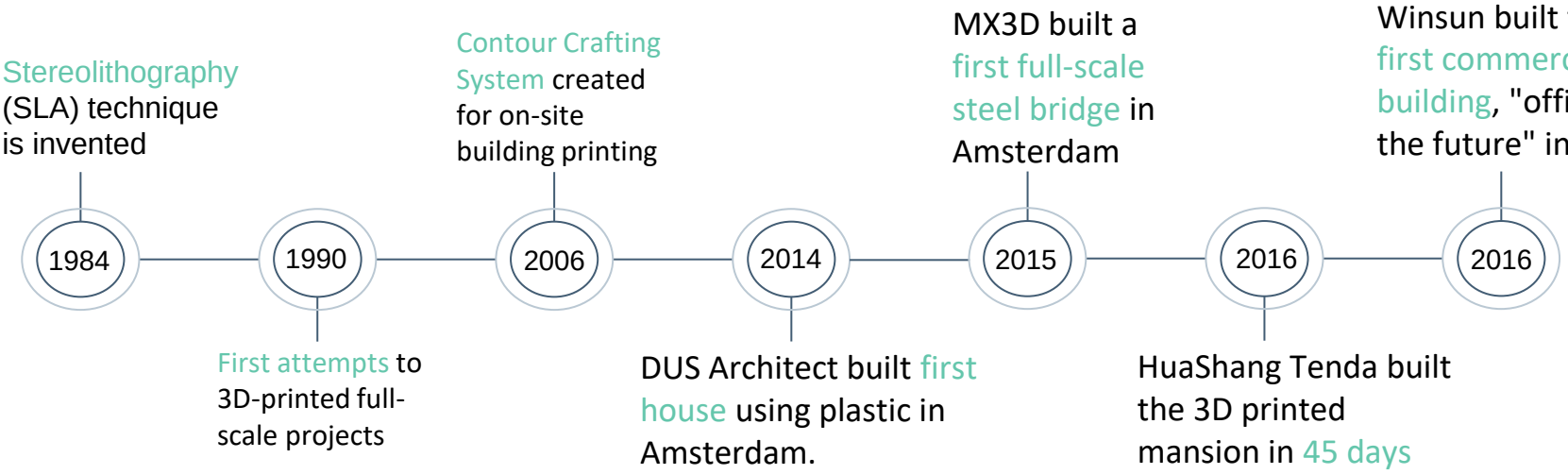
3D Printing in Construction History



Real-Estate Market and House Affordability

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Real-Estate Market-EU

- Both house and rent prices have surged in past decades
- More than 82 million EU citizens have spent more than 40% of their income on housing
- Tenants are more affected by increasing house prices, almost four times as likely than homeowners
- Main cities in Eurozone are experiencing real-estate bubble risk (score > 1.5)

Real-Estate Market-EU

Trends in House Prices and Rents (EU)

Source: Eurostats

UBS Global Real-Estate Bubble Risk Index-EU

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Real-Estate Market-US

- Low 30-year fixed rate mortgage to the record low of 2.8% last year
- Sales of existing and new houses are both increased by 5.6% and 19.3%
- Total supply of homes for sale hit historic lows in 2020
- Price-to-Income ratios keep soaring and up to 4
- The bubble index risk score is relatively unstable and overvalued (Score: 0.5~1.5)

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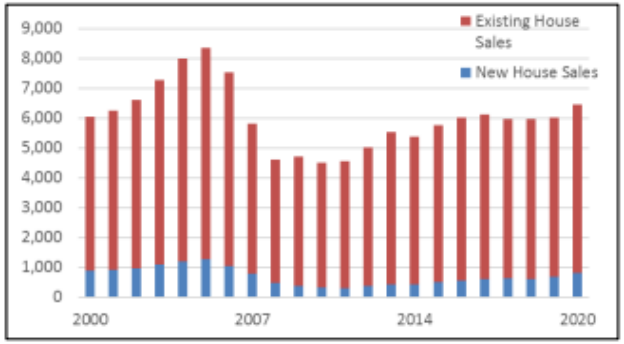
Real-Estate Market-US

Home for Sale Hit Historical Low

Source: The State of the Nation's Housing, Harvard University

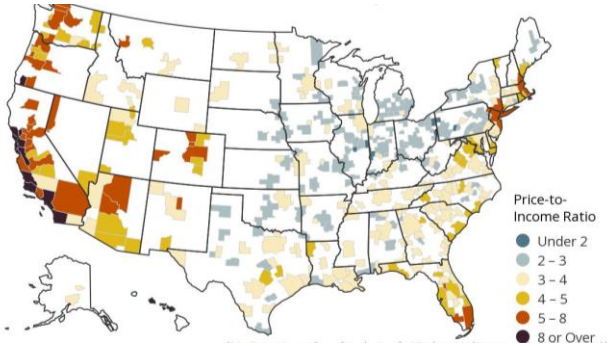
Real-Estate Market-US

Annual House Sales in thousands



Source: Department of Housing and Urban Development

Home to Income Ratio - US



Source: Joint Center for Housing Studies, Harvard University

UBS Global Real-Estate Bubble Risk Index-US

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House Affordability

- Social housing showed an uptrend in the globe as the housing price keeps displaying an upward trend.
- Eurozone has at least 700,000 people are living in emergency accommodation, 70% more than decades ago.
- US has 580,466 people experiencing homelessness, 38.9% are unsheltered.

3D-Printed houses’ potential in Green Buildings Market

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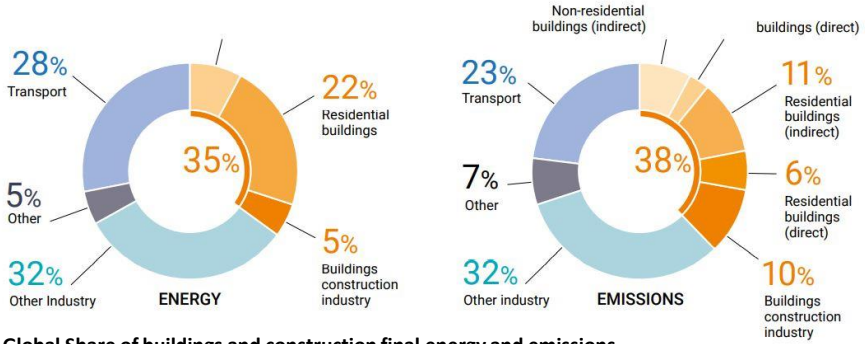
3D-Printed houses' growth potential in Green Buildings Market

Green building still has a long way to go:

- 104 of 194 countries signed the Paris Agreement, but only 68 of them obtained building energy codes.
- Carbon emission reached the highest level through building construction and emission ever although the global construction speed slowed to 2.6% since 2019.
- Nowadays, buildings are responsible for 6% for all global emissions, 38% of global carbon emissions, and 35% of global energy use.



Global Share of buildings and construction final energy and emissions

Source: THE 2020 GLOBAL STATUS REPORT FOR BUILDINGS AND CONSTRUCTION

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3D-Printed houses' growth potential in Green Buildings Market

3D printed house's market potential:

- Over 47% of the surveyed businesses planned to cover 60% green technology
- The carbon footprint for the 3D printed home can reduce 70%
- Reduces labor costs by 50%-80%, production time by 50%-70%, and construction waste by 30%-60%
- Market growth is expected to reach $4.63 million in 2021 at a compound growth rate of 21.7%.

Environmental Analysis

Environmental Analysis

Through the Life Cycle Analysis (LCA), we can evaluate whether 3D printed house is much more sustainable and has smaller impact on environment than the traditional construction process.

LCA: Analyzing environmental effects associated with the initial gathering of raw materials from the earth until the point at which all residuals are returned to the earth", or the so-called "cradle-to-grave process"

Evaluate the product's life cycle consumption and transform to carbon emission level

Environmental Analysis

Materials and process in 3D printed buildings

Materials	SimaPro Reference	unit	Building (kg)	Foundation (kg)	Roof (kg)
Cement+flyash	Portland cement, strength class Z 42.5, at plant/CH S	kg	25699.8	11160	9674.05
Silica fume	Silica sand, at plant/DE S	kg	2867.05	1245	1079.23
Sand	Sand, at mine/CH S	kg	42867.6	18615	16136.5
Water	Tap water, at user/CH S	kg	8014	3480	3016.6
Fibers	Glass fiber, at plant/RER S	kg	48	21	18
Transport	Lorry transport, Euro 0-4 mix, max payload RER S	kg	8394.93		
Transport of printer	Transport, lorry 16-32t, EURO5/RER S	tkm	500		
Transport of materials	Transport, lorry 16-32t, EURO5/RER S	tkm	50		
Ceramic floor tiles	Ceramic tiles, at regional storage/CH S	kg	170.2		
Timber floor boards	Glued laminated timber, outdoor use, at plant/RER S	m3	331		
U-PVC frame	Window frame, aluminum, U+1.6 W/m2K, at plant/RER S	m2	192		
Hardwood timber	Door, inner, wood, at plant/RER S	m2	331		
Electricity (1440kWh)	Electricity, medium voltage, at grid/CH S	kWh	795.28	345.35	300

Materials and process in conventional buildings

Materials	SimaPro Reference	unit	Building (kg)	Foundation (kg)	Roof (kg)
Brick (Imperial 9'')	Light clay brick, at plant/DE S	kg	30002	10956	
Cement mortar	Cement mortar, at plant/CH S	kg	7983	726	1079.23
Concrete block (aerated)	Aerated concrete block, type P4 05 reinforced	kg	6716	12906.85	
Concrete slab	Concrete, sole plate and foundation, at plant/CH S	kg	7097.14		
Sand and gravel	_16 sand, gravel and stone from quarry	kg	3312		
Concrete tiles	Ceramic tiles, at regional storage/CH S	kg			1991
Plaster board	Gypsum plaster board, at plant/CH S	kg	3088		
Softwood timber	Sawn timber, softwood, planed, air dried, at plant/RER S	m3	1362		
Timber floor boards	Glued laminated timber, outdoor use, at plant/RER S	m3	331		
U-PVC frame	Window frame, aluminum, U+1.6 W/m2K, at plant/RER S	m2	192		
Laminated floor	Three layered laminated board, at plant/RER S	m3	331		
Transport of materials	Transport of materials	tkm	3611.82	1487.61	67.91
Energy consumption	Electricity, medium voltage, at grid/CH S	kWh	3102.39	1285.06	61.26

Source: Elias Ali, Life Cycle Assessment of 3D Printing Houses

Environmental Analysis

Characterization results of the two alternatives

Impact Category	unit	3D printed building	Conventional building
Climate change	kg CO_2 eq	2.21E5	1.41E6
Ozone depletion	kg CFC-11 eq	0.017	0.0729
Human toxicity	kg 1,4-DB eq	9.95E4	2.57E5
Photochemical oxidant formation	kg NMVOC	980	5.37E3
Particulate matter formation	kg PM 10 eq	422	1.63E3
Ionizing radiation	kg U235 eq	7.41E4	3.39E5
Terrestrial acidification	kg SO2 eq	914	3.84E3
Freshwater eutrophication	kg P eq	88.5	225
Marine eutrophication	kg N eq	275	1.51E3
Terrestrial ecotoxicity	kg 1,4-DB eq	172	172
Freshwater ecotoxicity	kg 1,4-DB eq	1.77E3	4.41E3
Marine ecotoxicity	kg 1,4-DB eq	1.84E3	4.6E3
Agricultural land occupation	m2a	1.09E6	5.45E6
Urban land occupation	m2a	1.36E4	7.34E4
Natural land transformation	m2	144	759
Water depletion	m3	1.41E3	2.67E4
Metal depletion	kg Fe eq	1.19E4	7.23E4
Fossil depletion	kg oil eq	6.16E4	2.33E5

Source: Elias Ali, Life Cycle Assessment of 3D Printing Houses

- Top 5 toxic impact from both 3D and conventional construction is: Marine Ecotoxicity, Freshwater eutrophication, Human Toxicity, Freshwater Ecotoxicity, and Agricultural Land Occupation
- Except Terrestrial ecotoxicity, all other categories show conventional building is way more harmful to ecosystem

Product Analysis

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Product Analysis

Three of the famous 3D-printed residential houses for sale

Project Name	Landscape	Size	Company / Country	Price/sqft	Median price/sqft in the same area
Yhnova		1022 sqft	University of Nantes /France	£166	£240
Palari Villas		1450 sqft	Palari Group/ USA	$410	$483
S-squared		1,400 sqft	SQ4D/ USA	$214	$280

The price /sqft is all less than the median price of other houses in the same area, cheaper 20%~30%

Product Analysis

Product Advantages:

- Relatively Low Cost
- Infinite Design Possibilities
- Stronger vertical resistance
- Stronger thermal Insulation
- Sustainability

Product Disadvantages

- Size limitation
- Compete with mature real-estate market
- Lack of standard operating procedure and regulation protection

Summary and Future Outlook

Summary and Future Outlook

3D printed houses generate less construction waste and protect the environment by using recyclable materials. Moreover, it has economically advantageous for future developments. The cheaper, smaller 3D printed house can possibly solve house affordability and supply shortage.

3D printing technique is also ideal for remote and undeveloped areas. If Government cooperate with 3D printing companies, it will be feasible to make the urban redevelopment plan and alleviate potential real-estate bubble risk by building 3D printed houses.

However, the limitations by far are apparent, such as lack of horizontal resistance and size restriction due to immature structure techniques in 3D printing and materials characteristics.

All in all, several developments and research in the 3D printing house industry are still undergoing to solve the limitation on 3D printing techniques, and it will lead to the revolution of house construction methods and infrastructural changes in the future with no doubt

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