TRI COUNTIES COMMUNITY ACTION PARTNERSHIP

3D HOUSING FEASIBILITY STUDY AND ECONOMIC ANALYSIS

COMPLETED BY

MORRISON

CENTER FOR ECONOMIC DEVELOPMENT CED

FUNDED BY USDA

3D HOUSING FEASIBILITY STUDY
A Project of
TRI COUNTIES COMMUNITY ACTION PARTNERSHIP

TABLE OF CONTENTS

3D HOUSING FEASIBILITY STUDY
A Project of
TRI COUNTIES COMMUNITY ACTION PARTNERSHIP

SECTION I. – EXECUTIVE SUMMARY

Overview and Approach (Section II)
Recognizing the potential for 3D printed homes to contribute to the unique housing challenges facing Northern California – particularly Glenn, Colusa, and Trinity Counties – the Tri Counties Community Action Partnership, in cooperation with the United States Department of Agriculture, Rural Development, embarked on an effort to examine the feasibility of utilizing 3D-printing technology to increase and accelerate the supply of affordable housing within Glenn County and throughout Northern California.

To accomplish this, Morrison and the Center for Economic Development:

- Completed research on the industry; new developments in technology; market trends; and workforce needs.
- Conducted qualitative interviews with Northern California jurisdictions on building and permitting process to identify barriers and opportunities.
- Conducted qualitative interviews with regional home builders and other construction industry professionals to determine landscape of the regional housing market.
- Identified potential partnerships to support cooperative efforts in 3D building.
- Evaluated costs and economic landscape for 3D building.

Industry Background (Section III)
With a myriad of applications across industries, 3D printing has evolved over the past decade from a novel technology to a highly implemented solution in aerospace, medical, automotive, and fashion industries, among others.

Independent market research supports the likelihood of increased industry acceptance of 3D printing with Markets and Markets, a global market research firm noting that 3D printer sales are estimated to grow from $15 billion in 2023 to $34.5 billion by 2028, at a CAGR of 18.1 particularly highlighting 3D printing's ability to influence a decrease in manufacturing cost and process downtime and advancements in industrial-grade 3D printing materials.

Based on research by COBOD, the world leader in 3D construction printing solutions, there are currently 130 buildings that have been constructed using 3D printing globally, with North America representing the largest share of these buildings with 31 percent of all 3D printed buildings in North America.

Regional Market Conditions and Economics (Section IV)
The primary regional challenge facing Glenn County relative to the opportunity of 3D construction is a gap in availability of very low-income housing, which specific to the economic factors in the County, would represent a family of four earning $41,250 or less on an annual basis, according to the most recent data from the California Department of Housing and Community Development.

3D housing certainly can play a role in helping to meet the needs for very-low income housing, but likely would require a developer experienced in specifically building this type of housing

with braided funding from local and state government entities to ensure the economic viability of construction, as well as needed supports, such as rental subsidies, for individuals to enter into and maintain this housing. This has been a reality in traditional stick-built housing options that would transfer to 3D printed homes as well.

While sources vary, per square foot costs for 3D construction appear to be materially less on average than for stick built or modular construction, with significantly shorter construction time, less than a month compared to eight months to a year for stick built homes.

Potential Partnerships (Section V)

With 3D printing being a nascent industry, feedback provided noted that the community as a whole must be familiarized with the concept of 3D home printing first, with the building of any future community infrastructure for skills or workforce development secondary to the education of individual home buyers, single-family home builders and multi-family unit developers on the opportunities that exist in 3D home printing.

Morrison identified a number of regional organizations, with some contacted, that could serve as potential partners in best meeting the immediate and future potential needs to ensure a sustainable regional pathway for 3D home building.

Conclusions: Viability of 3D Industry in Region (Section VI)

Ultimately, the viability of the 3D printing industry in the North State relies on acceptance from the construction industry – the builders themselves – which is driven almost wholly by consumer demand and acceptance of the technology.

Qualitative interviews with a number of regional construction industry leaders planning and building departments demonstrate a clear pathway for 3D home construction in the North State.

As such, it is reasonable to conclude that 3D printing is an innovative technology that can be one of the tools in the toolbox to meet housing needs. Regional market conditions; proximity to educational institutions equipping and training a concrete workforce; strong community partnerships; and favorable economics could make Glenn County an ideal location for 3D home construction. ■

It is reasonable to conclude that 3D printing is an innovative technology that can be one of the tools in the toolbox to meet housing needs. Regional market conditions; proximity to educational institutions equipping and training a concrete workforce; strong community partnerships; and favorable economics could make Glenn County an ideal location for 3D home construction.

SECTION II. – OVERVIEW AND APPROACH

The 3D printing of homes is an emerging technology that is gaining traction nationwide.

Though a relatively nascent technology, the concept of 3D printing for homes or commercial buildings is relatively straightforward with development on 3D printing of buildings beginning more than 25 years ago.

Through the leveraging of innovative printing technology – large printers that can reproduce a 3D version of a design – 3D printing is emerging as a viable and recognized option for home construction, particularly making an impact in Northern California, with Redding home to the first concrete 3D printed house in California.

Recognizing the potential for 3D printed homes to contribute to the unique housing challenges facing Northern California – particularly Glenn, Colusa, and Trinity Counties – the Tri Counties Community Action Partnership, in cooperation with the United States Department of Agriculture, Rural Development, embarked on an effort to examine the feasibility of utilizing 3D-printing technology to increase and accelerate the supply of affordable housing within Glenn County and throughout Northern California.

To accomplish this, Morrison and the Center for Economic Development:

- Completed research on the industry; new developments in technology; market trends; and workforce needs.
- Conducted qualitative interviews with Northern California jurisdictions on building and permitting process to identify barriers and opportunities.
- Conducted qualitative interviews with regional home builders and other construction industry professionals to determine landscape of the regional housing market.
- Identified potential partnerships to support cooperative efforts in 3D building.
- Evaluated costs and economic landscape for 3D building.

The results of these efforts are documented in the pages of this study. ■

SECTION III. – INDUSTRY BACKGROUND

3D Printing Overview

With a myriad of applications across industries, 3D printing has evolved over the past decade from a novel technology to a highly implemented solution in aerospace, medical, automotive, and fashion industries, among others.

The earliest 3D printer originated in 1981, when Dr. Hideo Kodama invented one of the first rapid prototyping machines that created parts layer by layer, using a resin that could be polymerized by UV light.

However, it was not until the early 2000s that 3D printing solutions started to see true commercial applications, with a number of 3D printer technology manufacturers emerging to create solutions for household consumers and companies alike.

A 2023 industry report completed by Protolabs, a digital manufacturing service, surveyed one thousand users of 3D printing technology, finding that an outstanding 71 percent of the businesses surveyed used 3D printing more in 2022 than in 2021 and that 76 percent of manufacturers specifically produced more than 10 parts using a 3D printer, up from 49% in 2021. This demonstrates in part, a growing acceptance of 3D printing in everyday tasks within key industries.

Further independent market research supports the likelihood of increased industry acceptance of 3D printing with Markets and Markets, a global market research firm noting that 3D printer sales are estimated to grow from $15 billion in 2023 to $34.5 billion by 2028, at a CAGR of 18.1 particularly highlighting 3D printing's ability to influence a decrease in manufacturing cost and process downtime and advancements in industrial-grade 3D printing materials.

Fundamentals of 3D Printing in Construction
Technological advances are such that there are multiple 3D technology companies offer solutions for 3D printing – including printers targeted to the construction industry – using a wide variety of materials, including concrete; proprietary concrete mixes; mortar; plastic; metal; and even rice production waste.

Specialized 3D printers for home and building construction have the ability to convert a blueprint or CAD drawing to create a physical structure by gradually printing the material in layers. The 3D construction printer mainly focuses on the basic structure of the building, with the installation of components such as windows, doors, and electrical systems completed after the printing process.

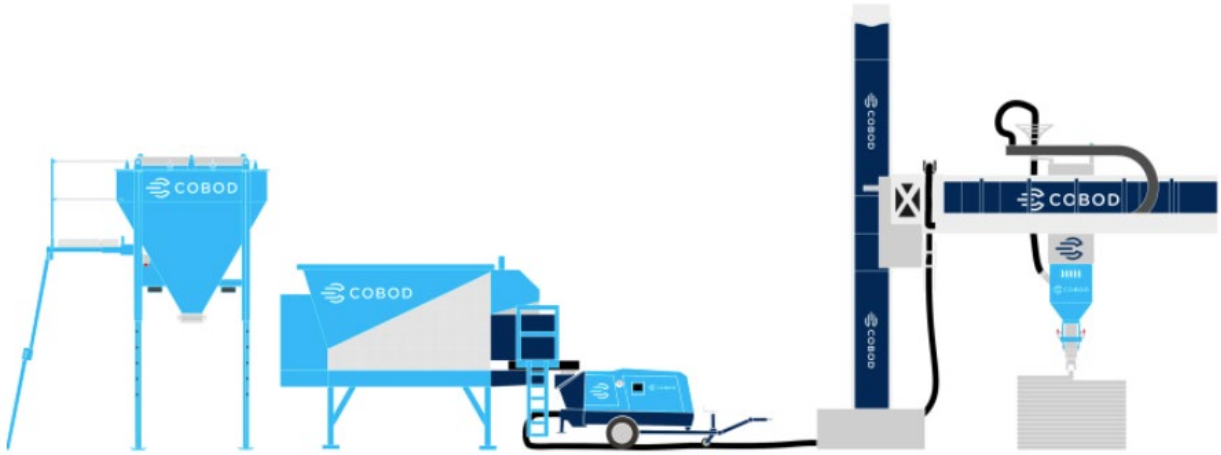
COBOD, the world leader in 3D construction printing solutions notes the following process for 3D building construction, following an order and process not unlike traditional stick-build homes.

1. Create a CAD drawing
The first step of printing a 3D house is creating a blueprint or CAD drawing. Usually, architects and engineers create a plan using computer-aided design (CAD) software. The plan contains a detailed description of the design and measurements of the building, such as the placement of windows, doors, and electrical and plumbing systems. Next, a 3D slicer software program helps the printer convert the detailed drawing into a printable file. This allows for the preparation of installing the printer onsite and estimating time and material usage.

2. Preparation – material and printer installation
The second step includes installing the 3D printer onsite, with additional equipment such as hardware and software solutions, a pump, a mini batch plant and a safety fence (if needed).

An analysis of the materials and environment is always needed. The analysis ensures the building will stand the weather and other environmental conditions. Then, depending on the result of the analysis, adjustments are made to the printing material mix. The most commonly used materials for 3D printed homes are currently a variation of concrete or mortar.

3. Printing the walls
The printer uses the converted drawing and prints the walls in layers, following the predetermined design of the house. Depending on the design and architecture, the printer's position or nozzle might be changed during the process. The nozzle defines the finish of the walls, which can be smooth or layered.



After the building's walls are printed, a common procedure is to keep the concrete moisturized for another 24 hours. Either water is sprayed on the walls, or the construction is covered in plastic to keep the moisture from evaporating. This procedure helps prevent cracks or flaws in the concrete.

One of the main advantages of 3D concrete printing is that it is time effective compared to conventional construction methods. Therefore, you can have the core of the building within hours or a few days, depending on the complexity of the building.

4. Additional installations
When the walls are dry, the final step is to complete all the necessary finishing touches. This step usually involves installing electrical and plumbing systems and adding doors and windows.

Overall Impact of 3D Printing in Construction Industry
Based on research by COBOD, the world leader in 3D construction printing solutions, there are currently 130 buildings that have been constructed using 3D printing globally, with North America representing the largest share of these buildings with 31 percent of all 3D printed buildings in North America.

Widely recognized and accepted market differentiations to stick-built homes include that 3D homes are: fireproof; demonstrate reduced costs vs. stick built homes; have a shorter construction timeframe; and support a reduced workforce need.

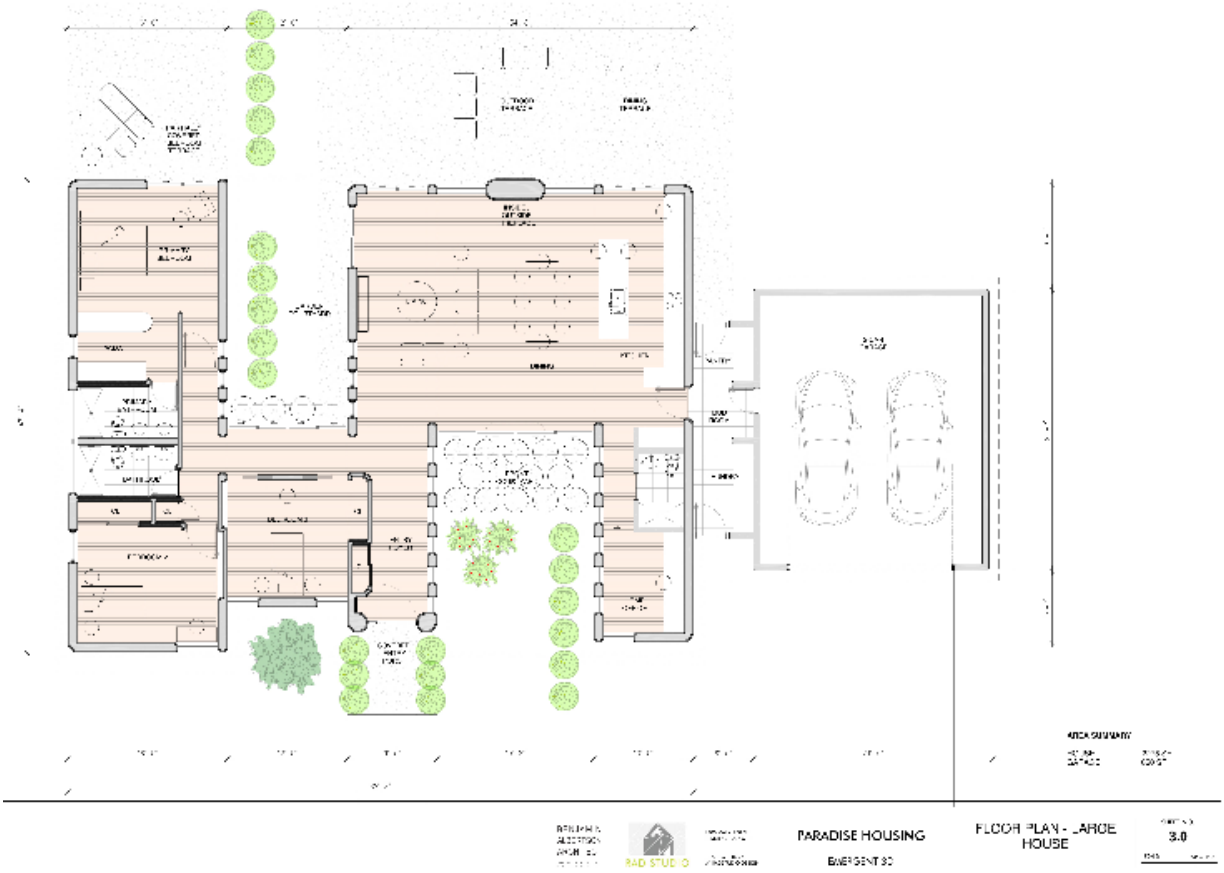
A key distinction that is important to note is that 3D printing technologies are largely owned by private companies (in this case construction companies) completing work, recognizing the need for expertise of equipment users and protecting the investment of technology.

Regional 3D Home Industry
The North State has become a hub of sorts for 3D home printing with Northern California home to the first on-site 3D printed home in California, the Enterprise Park Project completed by Redding-based company Emergent, and pictured below.

The Enterprise Park project was Emergent's first home and the first on-site 3D printed home in California.

Following this success, Emergent launched construction on their St. Mark's Street development consists of four 2-bedroom, 2-bath 1,150 square foot units, designed to provide housing for AccessHome clients. AccessHome provides affordable and desirable housing-related services for underserved populations and assists in meeting housing needs.

Emergent has also commenced building in Paradise, as part of fire recovery efforts, with the floor plan pictured below.



Given the experience of Emergent, and their growing footprint in the North State region, the viability of a thriving 3D home building industry would certainly rely on Emergent's expertise and industry leadership. Emergent has been actively involved in driving the 3D printing industry forward, particularly in the North State, working with a number of non-profit organizations, educational institutions, and technology providers to sustainably build the industry.

Opportunities to increase 3D home construction will be driven by the market, with qualitative interviews conducted through this study (see Section VI) noting that specialized construction firms like Emergent will fill a particular market niche that may not fit for traditional stick-build home developers.

With this in mind, building the regional 3D home printing industry in the near term may be best achieved by collaborating with Emergent to identify key projects and developments that 3D home printing could be a viable solution for.

Likely this will be driven by private industry, however with a number of non-profit organizations in the North State building affordable housing options to meet the needs of those they serve (AccessHome; Chico Housing Action Team; the Jesus Center) a key finding of this study is the potential for Tri Counties Community Action Partnership to leverage its prominence in community wellness to connect service providers with Emergent through a hosted event to identify key opportunities for future 3D building in the region. ■

SECTION IV. – REGIONAL MARKET CONDITIONS AND ECONOMICS

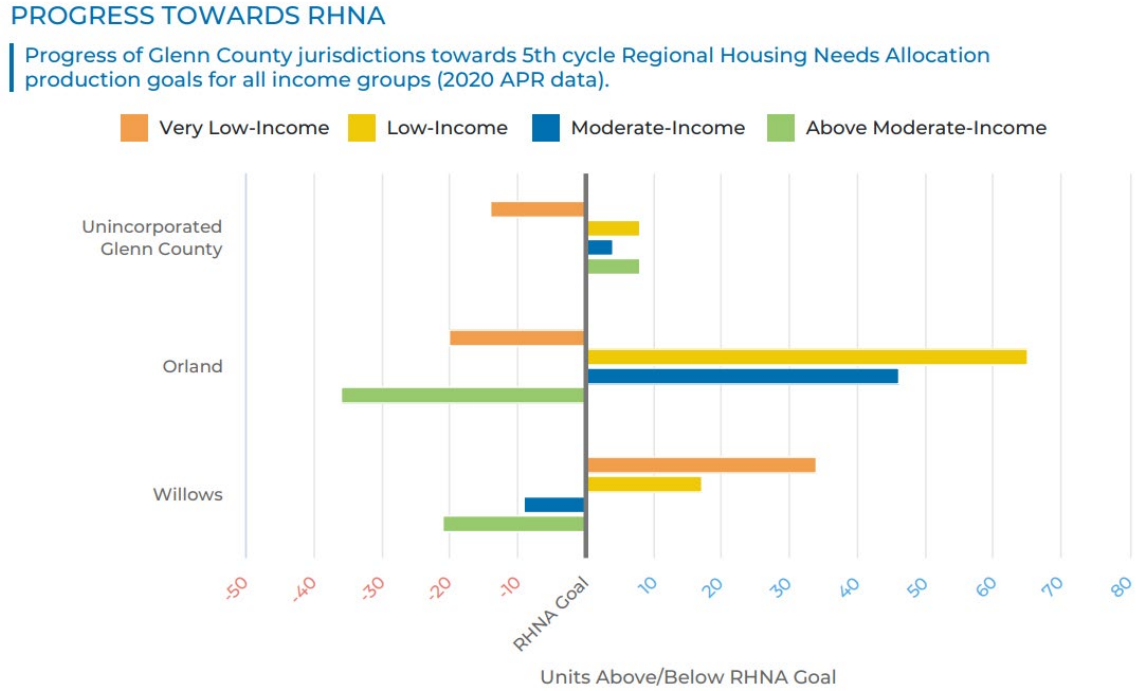
Regional Housing Conditions

As is the case with most California jurisdictions, third-party research demonstrates that Glenn County faces a housing shortage, particularly when it comes to serving very low-income residents.

The California Department of Housing and Community Development found that during the last ten years, housing production averaged fewer than 80,000 new homes each year, and ongoing production continues to fall far below the projected need of 180,000 additional homes annually. California requires that all local governments, including cities and counties, adequately plan to meet housing needs at all income levels.

This process starts with the state determining how much housing at a variety of affordability levels is needed for each region in the state, and then regional governments developing a methodology to allocate that housing need to local governments. California's local governments then adopt housing plans to show how the jurisdiction will meet local housing needs.

The most recent Affordable Housing Needs Report for Glenn County, published in 2022, found that Glenn County is exceeding its housing production goals as it relates to serving low-income, moderate income, and above moderate income residents in Glenn County, an accomplishment that illustrates an adequacy of housing for the majority of the income levels represented in the rural county.



Glenn County 2022 Affordable Housing Needs Report, California Housing Partnership

Further data supports Glenn County's strengths when it comes to overall housing needs: home ownership rates in Glenn County are much higher than the state average of 55.8 percent, with the Federal Reserve Bank of St. Louis showing an average of 62.26 percent of Glenn County residents are home owners.

Still, the primary gap and deficit in housing in Glenn County is very low-income housing, which specific to the economic factors in the County, would represent a family of four earning $41,250 or less on an annual basis, according to the most recent data from the California Department of Housing and Community Development.

While 3D housing poses particular promise as one type of housing to introduce into a mix of housing options for the County, there are a number of factors outside of the type of housing offered that would limit this as a viable solution to fully remedy the housing shortage for very low-income housing units.

3D housing certainly can play a role in helping to meet the needs for very-low income housing, but likely would require a developer experienced in specifically building this type of housing with braided funding from local and state government entities to ensure the economic viability of construction, as well as needed supports, such as rental subsidies, for individuals to enter into and maintain this housing.

Though 3D housing presents some efficiencies in building that allow for costs savings for developers, home owners, and renters alike, there are extenuating economic pressures that create significant hurdles to building very low-income housing, including costs of land, costs of bringing essential utilities to units, costs of environmental permitting, and overall costs of housing materials beyond just the concrete walls.

As detailed in an extensive report by Cal Matters, building affordable housing for low-income and very low-income residents is heavy reliant on government funding for the economics to pencil out. As illustrated in this report, shifting to a different type of housing simply is not enough to overcome these barriers.

"You cannot streamline your way out of this crisis," said Ben Winter, senior vice president at Linc Housing in Long Beach.

3D housing certainly can play a role in helping to meet the needs for very-low income housing, but likely would require a developer experienced in specifically building this type of housing with braided funding from local and state government entities to ensure the economic viability of construction, as well as needed supports, such as rental subsidies, for individuals to enter into and maintain this housing. This has been a reality in traditional stick-built housing options that would transfer to 3D printed homes as well.

With market demand – inclusive of individuals with the capital to support their interest in housing– driving the type of housing built, moderate income and above moderate income homes will likely continue to be the most viable channel for 3D printed homes.

Regional Workforce Conditions
Workforce in the construction industry has been a major challenge on national scope, though regional market data shows little challenges in meeting this need locally.

The Association General Contractors of America 2022 Workforce Survey Analysis shows that **93 percent of firms** report they have open positions they are trying to fill, and among them, 91 percent are having trouble filling at least some of those positions – particularly among the craft workforce that performs the bulk of the on-site construction work.

A reduced on-site construction workforce is a substantial benefit of 3D printed homes, the homes still do require a skilled workforce for plumbing and electrical work, as well as an ample supply of cement.

Still, Glenn County and neighboring Butte County have a relatively strong construction workforce to support either traditional stick build and 3D housing, with the workforce a contributing strength to the viability of home construction industry in general.

Construction Industry Employment and Percent of Total Employment			
Bureau of Economic Analysis			
County	Total Employment 2021	Construction Industry Employment 2021	Percentage
Butte, CA	107,818	6,449	6.0%
Colusa, CA	11,993	258	2.2%
Glenn, CA	13,250	591	4.5%
Lassen, CA	12,147	(D)	N/A
Modoc, CA	4,144	230	5.6%
Plumas, CA	9,607	821	8.5%
Shasta, CA	92,780	6,306	6.8%
Siskiyou, CA	20,789	1,167	5.6%
Sutter, CA	45,009	2,310	5.1%

Tehama, CA	26,675	1,678	6.3%
Trinity, CA	4,556	286	6.3%
Yuba, CA	31,851	1,723	5.4%

Market for Primary Inputs
A viable regional market for 3D home building is reliant on adequate access to key materials. California is the second-largest cement producer in the U.S. after Texas, producing nearly 10 million metric tons of cement yearly, according to the Portland Cement Association.

Portland and Blended Cement 2022

Location	Shipments (Metric Tons)
California	9,680,726
U.S. Total	90,664,338
Grand Total	109,790,424

Portland Cement 2022

Location	Shipments (Metric Tons)
Northern California	3,671,500
Total Shipments	83,812,144

Masonry Cement 2022

Location	Shipments (Metric Tons)
California	157,970
Northern California	28,991
U.S. Total	2,468,590

Blended Cement 2022

Location	Shipments (Metric Tons)
Northern California	8,134
Total Shipments	25,978,281

As shown above, there is ample availability of cement to meet future 3D construction needs.

Economics of 3D Printing
Comparing construction costs is a challenge without requesting estimates for specific floorplans; most contractors would be reluctant to do this unless the requesting party planned to build.

Information is available online to varying degrees, but it can be difficult to make direct comparisons as online estimates do not typically go into detail as to what is included (e.g., appliances, wiring, permits, land preparation, etc.). As much as possible, Morrison attempted to procure estimates of only the construction costs, including labor and materials.

3D Housing Costs:

Morrison identified several companies specializing in residential 3D construction that operate in California. These include:

- Emergent 3D, Redding, California.
- Mighty Buildings, Oakland, California.
- Alquist 3D, Greeley, Colorado.
- Icon Codex, Austin, Texas.

Morrison reached out to the California based firms (Emergent 3D and Mighty Buildings), but were able to get the most detailed estimates from Austin based Icon Codex. According to its website, Icon Codex began in 2018 with a promise to 3D print a house and unveil it at the SXSW

(South by Southwest) conference held annually in Austin, Texas. The SXSW conference focuses on an interesting mix of film, music, and emerging technologies.

Partnering with the international housing non-profit New Story, Icon Codex delivered the world's first permitted, 3D-printed home. Based in San Francisco, California, with offices in Atlanta, Georgia, and Mexico City, Mexico, New Story is known for its involvement in 3D developments around the world, including the world's first community of 3D printed homes in Nacajuca, Mexico

ICON states that it has now 3D-printed more than 100 homes and structures across the U.S. and Mexico, which it believes is the most completed by any construction tech company. They offer several models, with estimated construction cost ranges covering the costs of materials and labor.

Following is a recap of models for three-bedroom family homes with a midrange construction cost estimate of less than $500,000:

Model	**Shotgun**	**Dog Trot**	**Ranch**	**Raygun**	**Porch**
Beds	3	3	3	3	3
Baths	2	2.5	3	2	2
Sq. Ft.	1,934	2,227	2,431	1,934	3,340
Est. build cost	$260k - $301k	$303k - $351k	$335 - $388k	$348k - $403k	$368k - $426k
Midrange cost est.	$280,500	$327,000	$361,500	$375,500	$397,000
Midrange cost/sq. ft.	$145.04	$146.83	$148.70	$194.16	$118.86

Model	**Cornerstone 3/2**	**Cornerstone 3/2.5**	**Cluster 3/2**	**Cluster 3/2.5**
Beds	3	3	3	3
Baths	2	2.5	2	2.5
Sq. Ft.	2,549	2,805	2,499	2,749
Est. build cost	$372k - $431k	$401k - $464k	$410k - $475k	$445k - $515k
Midrange cost est.	$401,500	$432,500	$442,500	$480,000
Midrange cost/sq. ft.	$157.51	$154.19	$177.07	$174.61

In addition, Morrison reviewed Icon's options for single bedroom homes that may be suitable for individuals or couples:

Model	**Ranch 1/1**	**Shotgun 1/1**	**Dogtrot 1/1.5**	**Capsule 1/1**	**Porch 1/1**	**Dieste 1/1**
Beds	1	1	1	1	1	1
Baths	1	1	1.5	1	1	1
Sq. Ft.	932	1,017	1,146	936	1,591	1,029
Est. build cost	$155 - $179	$163 - $189	$181 - $210	$186 - $216	$185 - $215	$252 - $292

Midrange cost est.	$167,000	$176,000	$195,500	$201,000	$200,000	$272,000
Midrange cost/sq. ft.	$179.18	$173.06	$170.59	$214.74	$125.71	$264.33

Conventional Construction Costs:
Finding estimates for conventional construction without getting estimates for specific floorplans from contractors is also a challenge, and comes down to averages. These vary depending on the source and location of the construction.
A 2023 study published by StorageCafe and Yardi, a California-based real estate and property management software company respectively, found that California may be one of the best states in the nation to build a home rather than buy an existing one. A county-by county of the most affordable counties in which to build did not include Glenn, Colusa, or Tehama Counties, but did include adjacent counties Shasta and Butte as counties in which it is more favorable to buy than build, with median home prices of $419,500 and $440,995, respectively. These were not broken out by size of house, bedrooms and bathrooms, etc.

Information on construction costs varies depending on the source. A study published on February 24 by online real estate platform Houzeo states that the average cost per square foot to build a house in California is $200.15. By contrast, Element Homes, a general contractor with national presence including several locations in northern California, says the construction cost of modular homes ranges from $200 - $300 per square foot while the construction cost for stick built homes ranges from $400 - $600 per square foot. This is not broken out by county or region.

Homequide, a search engine for home service providers, states that the cost to build a house in California is $200 to $400 per square foot for a basic, builder-grade home. Homelight, a software platform for real estate agents and lenders, published a study of costs to build in California in 2024. While the tri-counties region was not broken out, Sacramento was noted as the least expensive of the areas studied, at $300 - $330 per square foot.

Summary:
While sources vary, per square foot costs for 3D construction appear to be materially less on average than for stick built or modular construction, with significantly shorter construction time, less than a month compared to eight months to a year for stick built homes. ■

SECTION V. – POTENTIAL PARTNERSHIPS

As part of its qualitative interviews with regional home builders and other construction industry professionals, the need for partnerships was heavily emphasized, particularly as a driving factor for consumer acceptance and support of 3D printing.

Builders who may have an interest in investing in equipment to offer 3D printing and existing 3D builders with the potential to expand current 3D printing production volumes, noted that the ultimate success of 3D printing will rely on consumer demand.

With 3D printing being a nascent industry, feedback provided noted that the community as a whole must be familiarized with the concept of 3D home printing first, with the building of any future community infrastructure for skills or workforce development secondary to the education of individual home buyers, single-family home builders and multi-family unit developers on the opportunities that exist in 3D home printing.

It is worth noting that several regional home builders contacted for qualitative interviews through this engagement were unaware of the concept of 3D home building and had little to no familiarity with the advancements in Northern California specifically towards 3D home building, further emphasizing the need for tailored industry outreach in addition to larger community educational efforts.

Morrison identified a number of regional organizations, with some contacted, that could serve as potential partners in best meeting the immediate and future potential needs to ensure a sustainable regional pathway for 3D home building.

Potential Partner	Overall Organization Purpose	Potential Partnership Role
Center for Economic Development	A division of the North State Planning and Development Collective at California State University, Chico, the Center provides regional leaders with accurate and timely information to address the socio-economic challenges and opportunities facing the region. By conducting high-quality research and leveraging the academic resources of CSU, Chico, the Center empowers regional leaders to make effective and informed decisions to best serve the needs of their clients, constituents, and communities.	Continued advancement of the industry; generation of community conversations. At this juncture, the Center could potentially be leveraged to host a regional summit of those involved in the regional 3D printing industry with an open time for questions of key community members.
Valley Contractors Exchange	A member-operated, non-profit association of contractors, suppliers and construction professionals.	Partnership for industry professional development to better help inform end consumers. This could include an event on-site at a recently built 3D home or at an active site for contractors and builders to ask questions and experience the materials and building process firsthand.
Associated	California's largest construction	Partnership for industry

General Contractors	trade association providing advocacy and services for general contractors and construction related professionals. In addition to providing tailored regional support, AGC has a nationwide reach through its governance structure that amplifies the reach and resources to members.	professional development to better help inform end consumers and support industry growth. This could include AGC hosting a regional event on-site at a recently built 3D home or at an active site for contractors and builders to ask questions and experience the materials and building process firsthand. Furthermore, this could also include AGC including a feature in their national newsletter or podcast or webinar forums on 3D home building. These podcasts and webinars could then be linked and promoted by regional partners and 3D home builders for added reach.
California State University, Chico	California State University, Chico is the only public four-year university within Butte, Glenn, and Tehama Counties. Specifically, the University's College of Engineering, Computer Science, and Construction Management would be leveraged as they provide application-based curriculum and hands-on learning experiences necessary to prepare students for their futures in the workforce. Undergraduate programs include advanced manufacturing and applied robotics; concrete industry management; and construction management among others.	Partnership for future course development on 3D home printing technologies and practices; supporting future workforce development. Opportunity exists to provide industry expert guidance from trends and learnings back to the industry through dedicated meetings and forums.
Butte College Applied Concrete Construction Certificate Program	Butte College is an accredited community college serving 15,000 students a year, primarily in the only public four-year university within Butte, Glenn, and Tehama Counties. The Certificate of Achievement in Applied Construction is designed to prepare students to meet entry-level requirements for skilled jobs in the	Partnership for future course development on 3D home printing technologies and practices to support the future workforce development and a skills pipeline at all levels of construction.

	construction industry covering a broad range of skills from foundation to finish.	

▪ ■

SECTION VI. – CONCLUSIONS: VIABILITY OF 3D INDUSTRY IN REGION

Ultimately, the viability of the 3D printing industry in the North State relies on acceptance from the construction industry – the builders themselves – which is driven almost wholly by consumer demand and acceptance of the technology.

To determine this viability, Morrison conducted qualitative interviews with a number of regional construction industry leaders, asking them a series of questions to learn about their background with 3D printing technology, known and perceived advantages, known and perceived disadvantages, and willingness to explore the adoption of 3D home printing in their own business models.

These qualitative interviews included a number of advantages to support a viable 3D housing industry.
Among others, advantaged expressed include:

- Cost of land (relative to the rest of the state).
- Ease of permitting in Glenn County (as well as Tehama and Colusa)
- Ability to obtain conventional home financing for homes.
- Ability to obtain conventional home insurance.
- Ability to meet consumer demand for fire safe building.
- Faster construction timeline: stick built homes averaging at least eight to 12 months; timelines for 3D are likely to average six to eight months. This considers any required permitting and infrastructure upgrades (curb, gutter, sidewalk, utilities connections).
- Easier to cool, especially in hot summers.
- Strong synergy with community partnerships and visions of other organizations.

Disadvantages shared include:

- Cost of 3D equipment (estimates are $1 million).
- Specialized consumer – need for education on safety and reliability of 3D homes.
- Nascent technology: unknowns on longevity; potential service interruptions.
- Specialized training for equipment and software technicians (though acknowledged this could be easily overcome).
- Lack of long-term developments to demonstrate viability.
- Lack of long-term knowledge on optimal materials.

Qualitative responses also included likelihood of use beyond housing including:

- Commercial warehousing
- Cold storage facilities

- Further research would need to be explored on food processing and manufacturing regulations to determine potential in this space.

The primary finding of the qualitative interviews was an interest in 3D home printing in general, but an acknowledgement that a traditional stick build home builder entering in this space would require additional skills, knowledge and investment in technology. Interviews supported that 3D printing is a niche market segment, best conducted by firms with established specialized expertise.

Furthermore, qualitative interviews with a number of regional planning and building departments demonstrate a **clear pathway for streamlined 3D home construction**. In essence, with an engineer certifying the materials (i.e. concrete) meet the minimum code requirements, there are no extraneous permitting needs beyond a traditional stick-built home.

Qualitative interviews demonstrate a clear pathway for streamlined 3D home construction. In essence, with an engineer certifying the materials (i.e. concrete) meet the minimum code requirements, there are no extraneous permitting needs beyond a traditional stick-built home.

As such, it is reasonable to conclude that 3D printing is an innovative technology that can be **one of the tools in the toolbox** to meet housing needs. Regional market conditions; proximity to educational institutions equipping and training a concrete workforce; strong community partnerships; and favorable economics could make Glenn County an ideal location for 3D home construction. ■