Pre-Disaster Planning
for Permanent Housing Recovery

volume four
BASIC PLANT DESIGN

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Pre-Disaster Planning for Permanent Housing Recovery

VOLUME 4: Basic Plant Design

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U.S. Department of Housing and Urban Development
Office of Policy Development and Research

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Illustrations and technical content from actual manufacturers are intended to demonstrate the overall process of delivering a factory-built home. We thank the following manufacturers for their contributions to this study in 2010.

Forest Homes
Louisiana Systems Built Homes
Palm Harbor Homes

About the NAHB Research Center

Located in Upper Marlboro, MD, the NAHB Research Center promotes innovation in housing technology to improve the quality, durability, affordability, and environmental performance of homes and home building products. Created more than 40 years ago as a subsidiary of the National Association of Home Builders (NAHB), the NAHB Research Center has established itself as the source for reliable, objective information and research on housing construction and development issues. Through its various testing and certification services, the Research Center seal is internationally recognized as a mark of product quality and an assurance of product performance.

Disclaimer

Foreword

Since Hurricane Katrina, many lessons have been learned about the importance of disaster preparedness planning and the impact of such planning on permanent residential housing recovery. The U.S. Department of Housing and Urban Development continues to explore new strategies for supporting state and local governments as they prepare and plan for disasters. In cooperation with the Federal Emergency Management Agency and the National Disaster Housing Task Force, we continue to address the temporary, interim, and permanent housing challenges that communities confront in a post-disaster environment.

This report introduces pre-disaster planning tools for permanent housing, with a special emphasis on community involvement in the planning process. We believe that when the community participates, a plan has a greater chance of success because it will reflect the specific housing needs and preferences of the residents. Our national disaster housing strategy recognizes that a "one-size-fits-all" approach is not sufficient for any disaster plan; thus, a flexible approach is encouraged within this report. In fact, the strength of this report is based on its utility and flexibility, which is captured within the electronic tool, worksheets, and checklist.

Planners will be able to use this report to guide the community through the planning process by identifying hazards, housing capabilities, and additional resources needed to implement a pre-disaster housing recovery plan. During the planning process, the community will discover what housing resources are needed to rebuild within a specified time and better understand if it is prepared based on current resources. By considering multiple rebuilding options, the community will be able to weigh the cost and benefits of any given recovery plan.

The planning tools presented in this report are limited to single-family housing needs. This is driven by a desire to keep this volume to a manageable size and not because of a view that other aspects are unimportant. It is vital that communities plan for multifamily and rental housing recovery as well.

Pre-disaster planning can provide a foundation for remaking neighborhoods into dynamic new communities following a disaster. This report provides tools to help make this a reality at the local level. Importantly, it does not direct but rather empowers the planner and community with the tools they need to find the right answer for their circumstance. This approach is aligned with our national disaster preparedness strategy, which emphasizes local involvement in the disaster planning process.

Raphael W. Bostic, Ph.D.
Assistant Secretary for Policy Development and Research

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Executive Summary

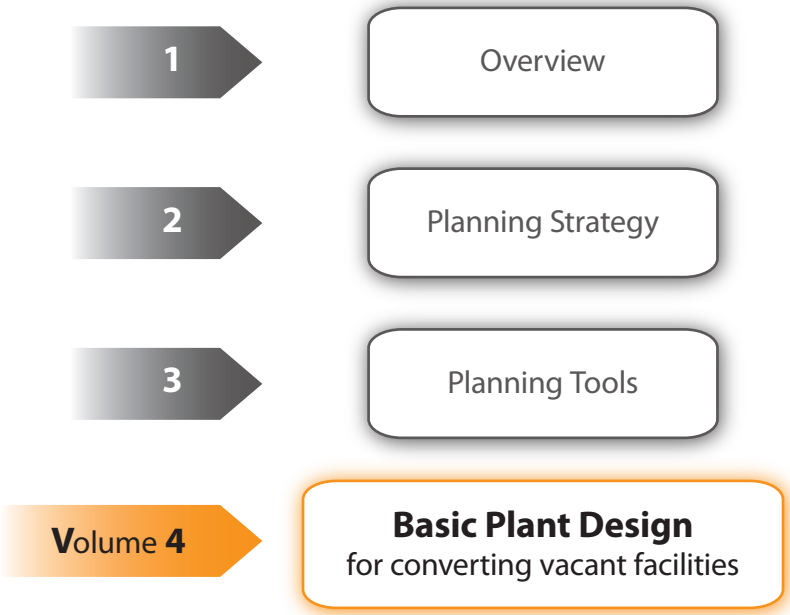
Disaster preparedness planning is important to communities and local governments throughout the country, and particularly relevant to those communities located in regions prone to frequent natural disasters. As a result, it is important to develop strategic planning tools that can assist the local communities and governments to prepare before, during, and after a disaster.

The objective of this study is to provide communities and governments with strategic planning tools they can use before a disaster to prepare for rapid reconstruction. These tools are intended to aid with hastening reconstruction of housing during the recovery phase. The planning tools presented within this document are designed to be used by federal, state, or local officials that are responsible for disaster recovery planning. Nonetheless, the authors envision the planners and community working together to develop a permanent housing recovery plan based on the unique needs of the residents and the natural hazards they may experience.

The content is presented in four short volumes. The first volume provides an overview of the permanent housing options, which include manufactured, modular, panelized, and site-built housing. The second volume provides a summary of the national disaster housing strategy, and describes a straightforward planning approach for estimating potential losses and expediting rebuilding. The third volume presents the House Capacity Calculator, which is an easy-to-use application that estimates required rebuilding time based on available house production capacity. The fourth volume describes the basic plant design requirements for manufactured, modular, and panelized housing.

This document serves as both a primer on the subject of permanent housing recovery and a guide to planning for the rebuilding of housing after a disaster. The step-by-step layout of this document allows the reader to progress through the planning process, which makes it ideal for the community participant who is not a disaster management professional. The planning tools have been designed to (1) identify critical planning issues, (2) identify various options available to the community, and (3) compare options in a straightforward manner. The reader is encouraged to use the House Capacity Calculator when considering multiple strategies for the long-term rebuilding of permanent housing. We also have included several worksheets and checklists to facilitate the planning process.

1 Introduction



Volume 4 defines the basic plant design requirements for producing factory-built housing (i.e., manufactured, modular, and panelized). This volume is a primer for the reader who is unfamiliar with factory-built house design, production floor layout, tooling, labor, inspection, quality assurance programs, transportation, and permanent installation requirements. If the planner and community are considering adding house production capacity as part of their recovery plan, then this volume will be a key resource.

The planner and community will need to determine if vacant facilities exist that have the characteristics to become good factory-built housing facilities. Generally, most facilities that have been used for manufacturing in the past (i.e., textile, automotive parts, durable consumer goods, and some warehouses) will be good candidates for factory-built housing production. Ideally, the facility will have an open floor plan that can accommodate shipping/receiving, staging of materials, house production, and the finished house (or system components). After identifying suitable facilities, we recommend developing a partnership with an existing factory-built manufacturer that is interested in expanding production capacity (temporarily) as part of the community's long-term recovery plan.

This volume includes a preliminary assessment worksheet that the planner can use when evaluating existing factory-built housing plants. The worksheet is intended to provide a preliminary overview of the plant, but not a comprehensive assessment of its capability to provide housing as part of a long-term recovery plan. For this, an expert must be consulted.

2 Manufactured Housing

Technical Approach

This chapter defines the typical Manufactured Housing production facility based on a general overview of the manufacturing practices at Palm Harbor Homes (a manufactured and modular housing manufacturer in central Florida) and basic industrial engineering principles. This characterization of the typical manufactured housing production facility is meant to establish a baseline for manufacturing requirements needed to produce a typical 1,600 square foot (s.f.) house floor plan. These requirements should be considered as benchmarks for: (1) vetting existing manufacturers of manufactured housing; and (2) providing guidance for the decision to operate a typical manufactured housing production facility.

It should be noted that the descriptions within this chapter do not fully capture all the production details of Palm Harbor Homes because its facility exceeds many of the baseline benchmarks in terms of the facility size and automated production equipment used. For the baseline manufactured housing production facility example represented in this chapter, the production layout and equipment specifications have been optimized to represent the minimum requirements—cost, facility size, equipment, and labor needs.

Palm Harbor Homes has two production facilities that are approximately 100,000 s.f. each, which includes space for its warehouse, office areas, and manufacturing operations. The production campus is located on approximately 35 acres and is well automated. Palm Harbor produces both HUD Code and modular housing interchangeably on the same production line. Palm Harbor is able to produce an average-sized 1,904 s.f. manufactured home. The maximum production capacity for this size home is equivalent to approximately 20 homes per 40 hours of production, which equals approximately 1,000 average-sized homes per year.

Manufactured House Design

The baseline home profiled in this chapter has a 1,600 s.f. floor plan. The entire house is constructed in the plant facility, typically using 2x6 wood studs and commonly used residential construction materials. The house design and quality control program must be approved by a third-party Design Approval Primary Inspection Agency (DAPIA) before construction of the house can start. The actual house construction and manufacturing process are inspected periodically by a third-party Production Inspection Primary Inspection Agency (IPIA).

The DAPIA ensures that the house design meets the requirements of the HUD Code. During construction of the manufactured home, multiple inspections are conducted based on the plant's quality control program and each house is inspected by the IPIA during at least one stage of its construction. The final HUD certification label is attached to the house once the construction is complete and all tests and inspections are performed successfully.

None of the typical building materials used have long lead times, but if specialty building products are specified or only one supplier is approved to provide a specific component or material, a shortage can be realized (especially during a major rebuilding effort). To avoid material supply issues, the managers of the production facility can:

1. Establish design specifications that are based on performance criteria that meet the HUD Code and can be easily confirmed by the quality control department
2. Maximize the manufacturing supplier base by specifying commonly used building products, equipment, and materials
3. Enter into contract supplier agreements to ensure that disruptions or delays of critical components can be avoided

The production planner and purchasing manager must strategically identify those components that typically require the longest lead times, and ensure they do not become supply chain issues. Table 2-1 lists a sample of typical construction materials that have long lead times and should be planned for accordingly.

Table 2-1: Typical Construction Materials with Long Lead Times

In-Plant
Any specialty components
Trim and finishing materials
Windows or doors
Fixtures or accessories
HVAC equipment

Baseline Production Facility Characteristics

When possible, it is recommended that the production facility be located in an uncongested area—ideally, no farther than 15 miles from a major transportation route. The recommended physical dimensions of the production facility must include a minimum height clearance of 24 feet to accommodate cranes and the height of a finished house. The support columns require spacing of 80 linear feet (l.f.) between them. The facility will require a loading dock area with four doors measuring 20 feet in width to accommodate incoming material handling, and one measuring 20 feet in width to accommodate outgoing shipments of finished panel and roof truss units. The loading dock needs to accommodate tractor trailer carriers for transport of the manufactured houses.

A minimum overall production space of 100,000 s.f. is required. This overall space needs to be segmented into areas for: (1) receiving; (2) shipping; (3) staging raw materials and components; and (4) production.

A warehouse area (approximately 35,000 s.f.) is also needed for material storage; this area can be part of the main production space or a separate building. Table 2-2 lists baseline production facility characteristics.

Table 2-2: Baseline Production Facility Characteristics

Item	Quantity	Comments
Floor plan space	100,000 s.f.	Manufacturing operations
Location	15 miles	Distance to nearest major transportation routes
Ceiling height	24 feet	To accommodate cranes and the finished house height
Column spacing	80 l.f.	Distance needed to maneuver work-in-process (WIP)
Loading dock	5 bays	Five 20-ft wide doors: 4 for incoming; 1 for outbound
Departments	4 areas	Receiving, shipping, staging, and production

Many existing vacant facilities may actually be well-suited for conversion to a manufactured housing production facility. These include facilities that were previously used to manufacture durable goods, automotive parts, textiles, warehouses, and factory-built housing. If such facilities are available, they can be evaluated to determine if the key production features exist or can be easily modified.

Physical Plant Utility Requirements

The production facility must include electrical, gas, septic/sewer, and water utilities. For the electrical, 480-volt, three-phase service is necessary in order to accommodate the electrical needs of typical tools and equipment used in a manufactured housing facility. An air-compressor system with a dryer is needed for power air tools (e.g., nail and screw guns). A waste disposal and recycling system must be established in order to limit the trash generated from raw material packaging and scrap lumber. Table 2-3 identifies utility services needed for the baseline manufactured housing facilities.

Table 2-3: Baseline Utility Requirements

Utility	Capacity	Use
Electrical	1,500-amp	Equipment/tooling (480-volt/240-volt, 3-phase)
Gas	36 cu-ft/s.f.	Heating equipment (depends on climate needs)
Sewer/septic	76,000-gal/month	Cleaning/workers
Water	76,000-gal/month	Cleaning/workers

Production Floor Layout

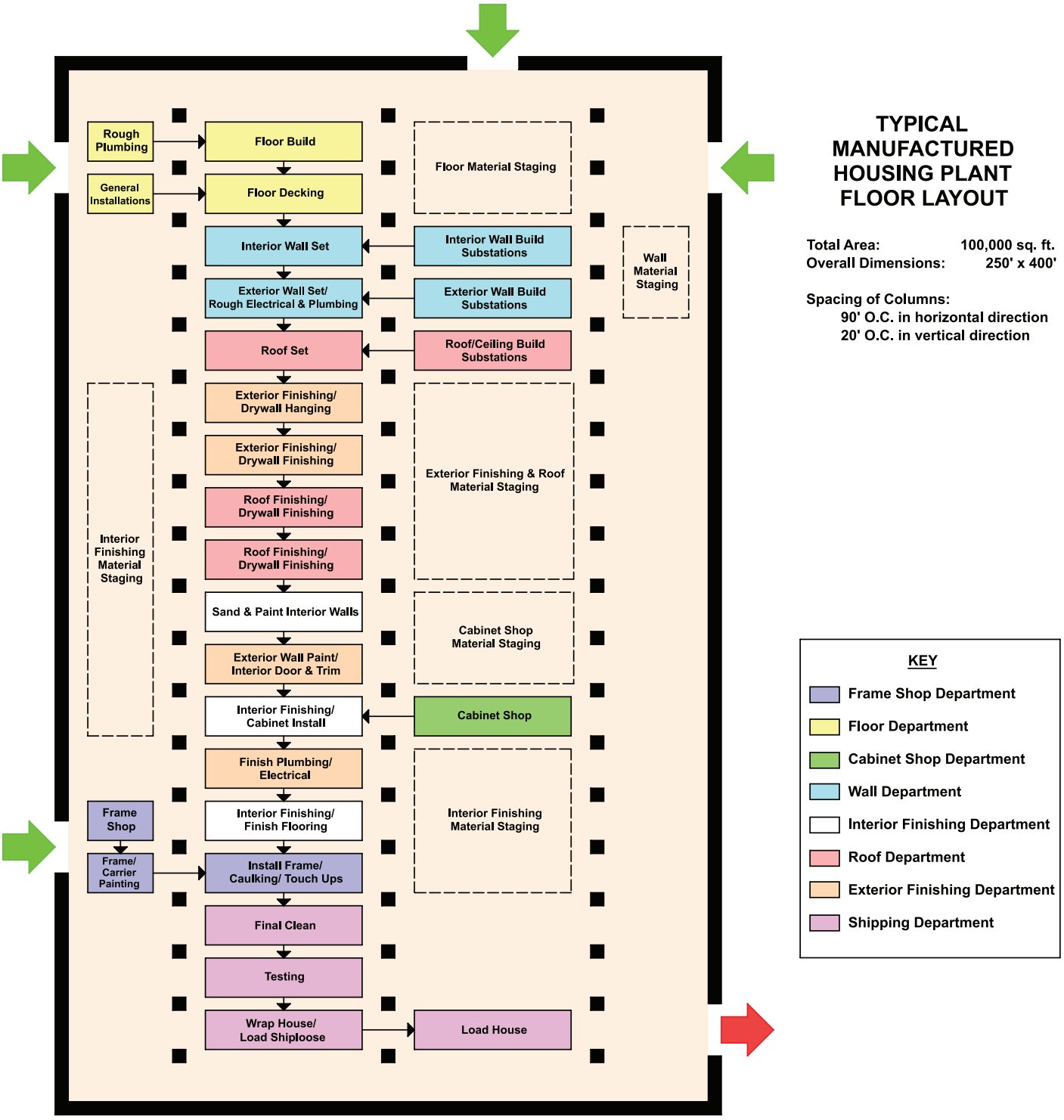
A typical layout for a manufactured housing plant is either arranged in a shotgun or sidesaddle production line configuration. A shotgun configuration is arranged with dual parallel lines with modules indexing or flowing lengthwise. A sidesaddle configuration is arranged in a single line with transverse indexing or flow of modules as illustrated in Figure 2-1 (see page 5), which will serve as our baseline example. Other types of production line configurations are L-shaped, U-shaped, and almost every conceivable combination, depending on the shape and characteristics of the facility. For our baseline example, we will assume a total production space of 100,000 s.f.

The production layout in a manufactured housing plant has a main production line and subassembly stations that feed the main line. Activities required to produce manufactured housing are listed in Table 2-4.

Table 2-4: Production Activities Required by Workstation

Department	Station Name	Location	Description of Station Tasks
Floor	General installations	Subassembly	Prep showers/toilets/tubs for installation
Floor	Rough plumbing	Subassembly	Prep rough plumbing line
Floor	Floor build	Main line	Frame floor and install rough plumbing
Floor	Floor decking	Main line	Insulate floor, install decking, and install showers/toilets/tubs
Cabinet shop	Cabinet shop	Subassembly	Assemble cabinets
Walls	Interior wall build	Subassembly	Build interior walls
Walls	Interior wall set	Main line	Set in place interior walls
Walls	Exterior wall build	Subassembly	Build exterior walls
Walls	Exterior wall set/rough elec & plumb	Main line	Set in place exterior walls
Roof department	Roof/ceiling build	Subassembly	Roof frame/ducts/electrical wiring
Roof department	Roof set	Main line	Install roof on unit
Exterior finishing	Exterior finishing/drywall hanging	Main line	Exterior insulation/install drywall
Exterior finishing	Exterior finishing/drywall finishing	Main line	Exterior sheathing/tape and 1st coat of mud and dry
Roof department	Roof finishing/drywall finishing	Main line	2nd coat of mud and dry/install insulation and shingles
Roof department	Roof finishing/drywall finishing	Main line	3rd coat of mud and dry/install shingles
Interior finishing	Sand & paint interior walls	Main line	Sand and paint interior walls
Exterior finishing	Exterior wall paint/interior door & trim	Main line	Paint exterior/install interior doors and trim
Interior finishing	Interior finishing/cabinet install	Main line	Install cabinets, vanity and countertops and appliances
Exterior finishing	Finish plumbing and electrical	Main line	Install electrical/plumbing fixtures and outlets
Interior finishing	Interior finishing/finish flooring	Main line	Install carpet, tile and/or hardwood
Frame shop	Frame shop	Subassembly	Build the chassis
Frame shop	Frame/carrier paintings	Subassembly	Paint chassis
Frame shop	Install frame/caulking and touch up	Main line	Attach house to chassis/caulking and touch-up paint
Shipping	Cleaning	Main line	Interior finishing and cleaning
Shipping	Testing	Main line	System testing
Shipping	Wrap/shiploose (furniture, etc.)	Main line	Wrap house and load shiploose—prep for shipping
Shipping	Load house	Main line/docking bay	Load house on carrier

Figure 2-1: Traditional Sidesaddle Configuration for Manufactured Housing Plant



Existing commercial or industrial facilities can be adapted to allow for the baseline production, even if the final layout is a variation of Figure 2-1. The typical process flow is illustrated in Figure 2-2 (see page 7). A new facility can also be built to achieve the baseline production requirements. Furthermore, many facilities of existing manufactured housing suppliers may actually vary significantly from Figure 2-1 depending upon the equipment selected, the degree of automation that is used, and facility configuration. Photo 2-1 shows the Wall Set Area within a Palm Harbor facility.

Photo 2-1: Wall Set Area
Source: Palm Harbor Homes

Tooling Requirements

The typical manufactured housing production facility has some automation, but much of the construction work can also be done manually. Some housing components, such as roof trusses, arrive at the plant as purchased, pre-assembled parts rather than being built at the plant. Much of the tooling is for woodworking, steel fabrication, carpentry, and a wide range of department-specific tasks.

The baseline plant must have typical tooling and equipment for transport and material handling, which includes dollies, fork trucks, cranes, and lifts. Tables 2-5 through 2-12 list the tools and equipment required for use within the production facility. All costs were sourced in March 2010.

Table 2-5: Tools and Equipment for the Frame/ Chassis Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Chassis jig	1	$10,000	$10,000
Welding machine	3	$500 [a]	$1,500
Soldering torch/kit	2	$250	$500
4-ton crane with bridge rails	2	$160,000	$320,000
Total Cost			**$332,000**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 2-6: Tools and Equipment for the Floor Department

Location of Usage	Quantity	Market Price	Subtotal Cost
Floor jig	1	$9,000	$9,000
Chop saw	2	$400	$800
Reciprocating saw	1	$250	$250
Beam saw	1	$150 [a]	$150
Gang-nail press with radial-arm saw	1	$18,000	$18,000
Lumber cart with flip deck	1	$21,000	$21,000
Air compressor pump	1	$9,000	$9,000
Impact wrench	2	$200	$400
Nail gun	6	$250	$1,500
Drill	4	$100	$400
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
4-ton crane with bridge rails	1	$160,000	$160,000
Total Cost			**$255,500**

For cost details about superscripts "a" through "g" please see the Appendix.

Figure 2-2: Typical Manufactured Housing Plant Process Flow

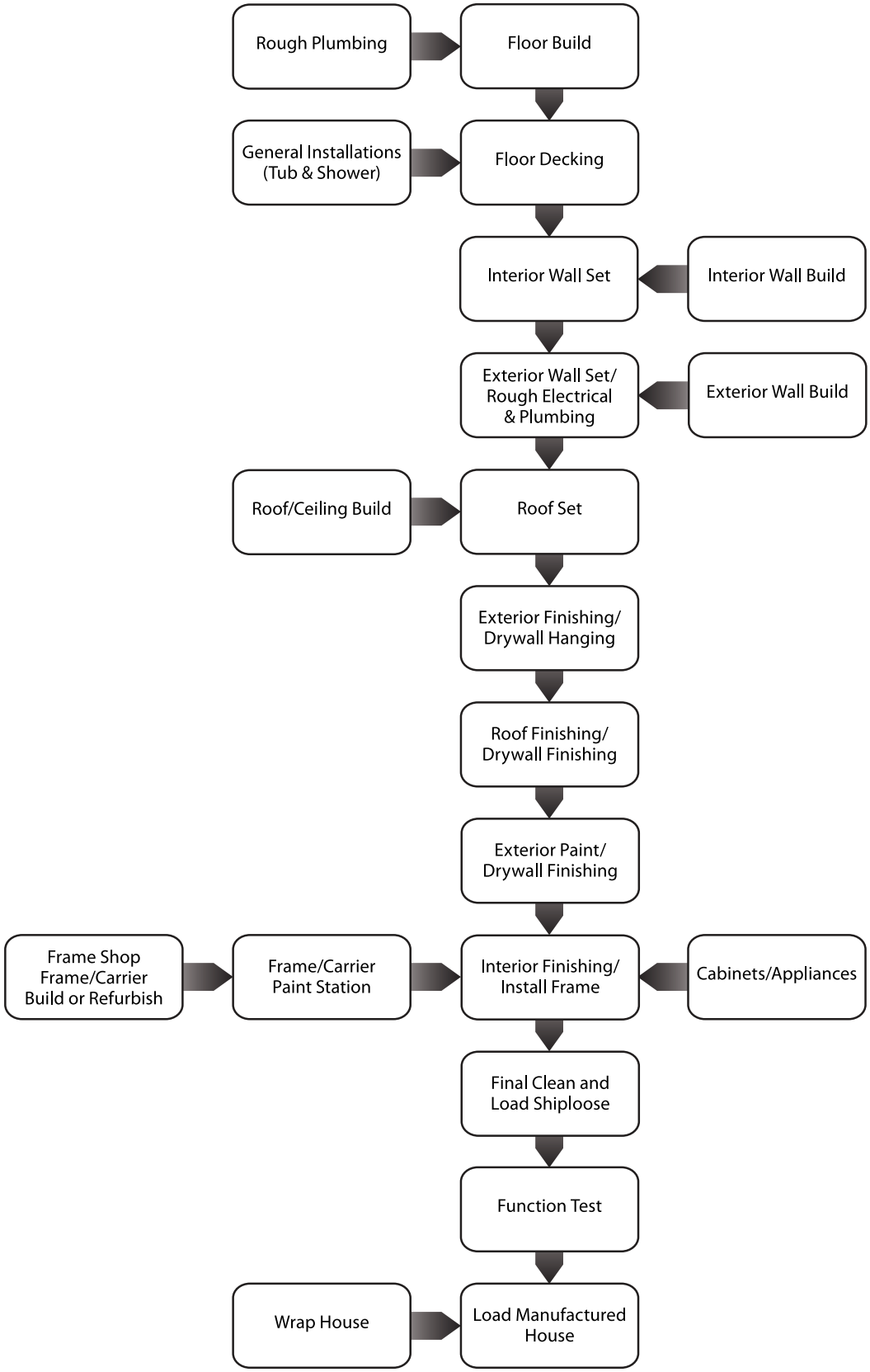


Table 2-7: Tools and Equipment for the Cabinet Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Miter/radial-arm saw	2	$450	$900
Chop saw	3	$400	$1,200
Table saw (saw stop, 14 inch)	1	$4,200	$4,200
Hot-melt glue system	1	$3,500	$3,500
Face-framing machine (drill)	1	$11,500	$11,500
Router	3	$100	$300
Belt sander	1	$1,000 [a]	$1,000
Clamp	5	$20	$100
Brad gun	2	$250	$500
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
Total Cost			**$58,200**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 2-8: Tools and Equipment for the Wall Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
1-ton crane with bridge rails	2	$55,000	$110,000
Table saw	1	$4,500	$4,500
Miter/radial-arm saw	2	$450	$900
Reciprocating saw	1	$250	$2 50
Cordless drill	3	$100	$300
Router (1.5 hp)	2	$100	$200
Nail gun	7	$1,750	$1,750
Total Cost			**$117,900**

Table 2-9: Tools and Equipment for the Interior Finishing Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Miter/radial-arm saw	2	$450	$900
Texture sprayer	1	$8,000	$8,000
Airless pump	1	$5,000	$5,000
Push cart	1	$6,500	$6,500
Router	3	$100	$300
Ames mud-tool set	1	$4,000	$4,000
Sander	2	$400	$800
Carpet stretcher	1	$150 [a]	$150
Wet saw	1	$4,300 [b]	$4,300
Miter/radial-arm saw	2	$450	$900
Nail gun	2	$250	$500
Total Cost			**$31,350**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 2-10: Tools and Equipment for the Roof Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
4-ton crane with bridge rails	1	$160,000	$160,000
OSB decking monorails	2	$25,000	$50,000
Scaffold system	1	$140,000 [a]	$140,000
Miter/radial-arm saw	2	$450	$900
Table saw	1	$4,500	$4,500
Sabre saw	4	$250	$1,000
Reciprocating saw	1	$250	$250
Nail gun	5	$250	$1,250
Ceiling spray equipment)	1	$25,000	$25,000
Safety harness, strap, & cable	2	$5,500	$11,000
Total Cost			**$393,300**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 2-11: Tools and Equipment for the Exterior Finishing Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Metal hand brake (14 inch)	1	$6,500	$6,500
Table saw	1	$4,500	$4,500
Miter/radial-arm saw	2	$450	$900
Sabre saw	2	$250	$500
Nail gun	3	$250	$750
Total Cost			**$13,150**

Table 2-12: Tools and Equipment for the Shipping Department

Location of Usage	Quantity	Market Price	Subtotal Cost
Di-electric tester	3	$1,500	$4,500
Circuit continuity tester	8	$25	$200
Breaker test/torque screwdriver	4	$250	$1,000
Air & water test/100-psi pressure gauge	4	$25	$100
Gas tester/mercury manometer	2	$90	$180
HVAC duct-blaster kit	1	$1,500	$1,500
Ladder	4	$150 [a]	$600
Nail gun	7	$250	$1,750
Diesel forklift (8,000 lbs)	2	$35,000	$70,000
Hydraulic lifter	6	$9,000	$54,000
Transport carriers	6	$7,000	$42,000
Trucks (pre-owned)	4	$50,000 [b]	$200,000
Total Cost			**$375,830**

For cost details about superscripts "a" through "g" please see the Appendix.

Labor Requirements

Generally, given the specific construction requirements of manufactured housing, the baseline plant assumes that plant supervisors have some experience producing manufactured homes. This experience is essential to ensuring that quality and construction practices are followed to meet the HUD Code. Although the construction labor does not require specialized training, the baseline skill sets required include the ability to read a tape measure and drawings/blueprints and to work with residential construction tools and equipment. The general construction labor is classified as "direct labor" for the production of manufactured housing. Table 2-13 lists the direct labor requirements and typical hourly rates for each type of trade based on Occupational Employment Statistics for the Residential Construction Industry (2008).

Table 2-13: Baseline Direct Labor Requirements

Direct Labor Trade Type	Quantity of Labor Needed	Labor Rates
Welder	4	$17.38/hr
Carpenter	36	$19.71/hr
Cabinet maker	3	$18.11/hr
Carpenter helper	7	$12.47/hr
Plumber	5	$22.74/hr
Drywall installer	6	$19.02/hr
Drywall tapers	3	$23.17/hr
Drywall finisher	8	$19.34/hr
Electrician	5	$22.22/hr
Electrician helper	2	$12.81/hr
Painter	12	$16.21/hr
Tile setter	5	$19.50/hr
Roofer	9	$15.91/hr
General construction helper	5	$12.71/hr
Truck driver	1	$18.35/hr

Equally essential to the production of manufactured housing are the management and professional staff. The management, engineering, quality, accounting, marketing, purchasing, and human resources staff are classified as "indirect labor." Table 2-14 lists the indirect labor requirements and approximate annual salary considerations.

Table 2-14: Baseline Indirect Labor Requirements

Indirect Labor	Average Annual Salary
General manager	$150,000
CFO	$85,000
HR director	$65,000
Accounts payable and receivable	$36,000
Purchasing manager	$65,000
Operations clerk	$45,000
Engineering manager/QA	$80,000
Production/plant manager	$65,000

The estimated annual total labor cost for the baseline manufactured housing plant is summarized in Table 2-15. The actual labor cost will vary based on the location of the plant and the skill level of the workers.

Table 2-15: Summary of Total Labor Costs

Labor Type	Total Labor Cost
Direct labor	$4,215,286
Indirect labor	$591,000
Overall Total Labor	**$4,806,286**

Key Labor Functions within the Facility

The general manager, production/plant manager, and/or a planner generate and manage the production schedule at the facility. These persons should have experience in manufactured housing facilities because compliance with the DAPIA- and IPIA-approved systems is critical to the successful production of manufactured housing. The purchasing manager is responsible for establishing and maintaining strong partnerships with suppliers, vendors, and subcontractors. Finally, functional-area supervisors, in coordination with the production manager, plan ahead and prioritize material replenishment based on production.

Inspections and the Quality Assurance Program

Manufactured housing relies on third-party inspection and approvals to ensure that the houses are built in accordance with the HUD Code. The quality control process is integrated into every workstation and each manufactured home includes a Quality Control Traveler Form that documents the "history" of construction for the unit; it includes any problems found and corrective actions taken. The baseline manufactured housing plant must have quality control inspectors to evaluate each phase of construction; typically a quality control inspector is assigned to each department (which includes multiple workstations).

The quality control inspectors use checklists and department meetings to incorporate continuous improvement into the manufacturing process. Any changes to the quality assurance program must be approved by the third-party DAPIA and IPIA to ensure that these improvements will continue to produce houses that are compliant with the HUD Code.

Every producer of manufactured housing has to develop and implement a quality assurance program. This task is typically the responsibility of the engineering staff in cooperation with the third-party DAPIA. Generally, it takes about two months to develop the necessary DAPIA and IPIA documentation for a plant. Performance specifications and inspection protocols are defined during this process, even though the quality staff will perform the actual inspections of components and finished goods. When a manufactured house ships from the plant, it will have been inspected by the third-party IPIA, and it will have the HUD certification label affixed.

Critical Construction Items when Producing Manufactured Housing

Material supply issues and shortages can be minimized by identifying and establishing relationships with suppliers located within 500 miles of the production facility, entering into supply agreements with multiple sources, and maintaining inventory lead times of three to four days. The plant must also maintain alternative suppliers that can meet HUD Code specifications; this is critical for components such as doors, windows, and roofing parts.

Managing the flow of material throughout the plant is critical to the timely production of houses. Keeping a minimum supply of material on the production line and planning for the houses that will be produced well in advance of the actual production are recommended. Additional staging space will be necessary on the production line, so the layout will be important to minimize the chances of bottlenecks. The purchasing manager should have knowledge of HUD Code products, and at least one year experience working in a manufactured housing plant.

Production Capacity Strategies

The baseline production capacity for the manufactured housing facility assumes a single shift at 40 hours per work week. The daily production schedule can be arranged as management sees fit; it could be a typical 8-hour, 5-day-a-week schedule or another variation on a 40-hour week schedule. Generally, the schedule will conform to the labor availability and production requirements.

Production capacity can be increased by adding a second shift (which will require additional labor). If this is to be done, the plant must have access to additional construction labor and management in the vicinity. Generally, the labor bottleneck will be the management and professional staff, not the general construction labor.

Production capacity can be increased by:

1. Changing from the standard 40-hour week to a 60-hour week (e.g., 12-hour, 5-day-a-week schedule). Typically, a manufacturer may prefer this approach before committing to a full second shift.
2. Adding a second shift (which will require additional labor). If this is to be done, the plant must have access to additional construction labor and management in the vicinity. For a multiple-shift strategy to be successful, the planning and construction procedures must be well defined and executed because the second shift will need to continue in a "seamless" manner the work that was started by the first shift.

Achieving the maximum production capacity will typically involve additional labor beyond a single shift. Three production capacity scenarios are provided in this chapter that can be considered based on the production needs of the jurisdiction that is rebuilding. See Table 2-16 for the production capacity options based on a 1,600 s.f. house design.

Transport and Installation Requirements

For the baseline capacity condition, the manufactured house is transported from the plant to the jobsite where it is installed on a permanent foundation. It is essential to use a licensed set-up manager and a lead setter who are familiar with the HUD Code and critical issues such as wind zones. A crew consisting of one crane operator and three to six setters should be able to install a typical 1,600 s.f. house during an eight-hour shift. A 20-ton jack and two translift crawlers are normally used as part of the installation process. However, subcontractors must first perform approximately $10,000 worth of site preparation/demolition, sewer and drainage installation, and a 200-amp electrical-service installation.

The entire set-up process can be subcontracted to a licensed builder. Regardless of who performs the set up, a set-up inspection by the local building official is required prior to the issuance of a Certificate of Occupancy.

Table 2-17 lists the tools and equipment required for set up, followed by Table 2-18, which lists the direct labor required for set up.

Table 2-16: Production Capacity Scaling Options

Strategy	Direct Labor	Equipment/Automation Level	Production Capacity
Baseline (1 Shift)	120	Low	7 houses/week 350 houses/year
Baseline (1 Shift w/OT)	120	Low	10 houses/week 500 houses/year
Increase labor size (2 Shifts)	200	Low	14 houses/week 700 houses/year

Table 2-17: Tools and Equipment for Installing/ Setting the House at the Jobsite

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Crane (rented)	1	$1,200 per hour	$9,600
Generator	1	$5,495 [a]	$5,495
Air compressor	1	$2,300 [b]	$2,300
Sabre saws	2	$100	$200
Sledge hammer	2	$66 [c]	$132
Reciprocating saw	1	$250	$250
Level and tape measure	3	$25 [d]	$75
String line and chalk line	3	$30 [e]	$90
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
Hand trucks	1	$100 [f]	$100
Chainsaw	2	$200 each [g]	$400
½-hp router	2	$100 each	$200
Chop saw	2	$400 each	$800
Cordless drill	2	$100 each	$200
Total Cost			**$54,842**

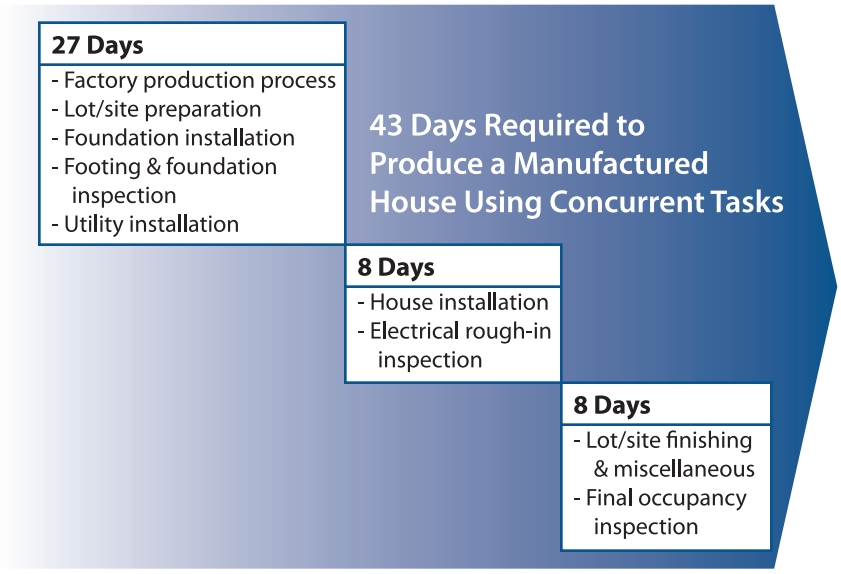
For cost details about superscripts "a" through "g" please see the Appendix.

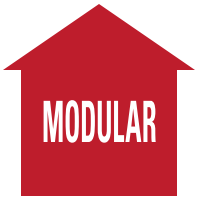
Table 2-18: Direct Labor Required for Installation at the Jobsite

Direct Labor	Quantity	Labor Rates
Crane operator	1	$23.75/hr
Home installer	4	$15.09/hr
Electrician	1	$22.22/hr
Plumber	1	$22.74/hr
HVAC installer	1	$19.64/hr

Figure 2-3 graphically shows that if concurrent tasks are scheduled and executed where possible, then the time to produce and install a manufactured house can be compressed to 43 days. This includes the complete process for in-house (factory) production and jobsite installation. An average of one, 1,600 s.f. manufactured house can be produced during approximately 10 days of the in-house production process, which does not include queuing time for scheduling its production. The jobsite time requires approximately six weeks from site preparation to installation of this size house, which does not include delays related to items such as weather or inspections. If concurrent activities are *not* executed, such as beginning production of a house at the plant while conducting site-preparation activities (for the same house), then the total sequential production schedule could expand to as many as 52 days to produce a house this size once the order has been received and the house enters the production process.

Figure 2-3: Total Compressed Time Required to Produce and Install a Manufactured House





3 Modular Housing

Technical Approach

This chapter defines the typical Modular Housing production facility based on a general overview of the manufacturing practices at Louisiana Systems Built Homes (a modular housing manufacturer in Louisiana) and basic industrial engineering principles. This characterization of the typical modular housing production facility is meant to establish a baseline for manufacturing requirements needed to produce a typical 1,600 s.f. house floor plan. These requirements should be considered as benchmarks for: (1) vetting existing manufacturers of modular housing; and (2) providing guidance for the construction of a typical modular housing production facility.

It should be noted that the descriptions within this chapter do not fully capture all the production details of Louisiana Systems Built Homes (LASB Homes) simply because their facility is currently in the process of being upgraded. For the baseline modular housing production facility example represented in this chapter, the production layout and equipment specifications have been optimized to represent the minimum requirements—cost, facility size, equipment, and labor needs.

LASB Homes has one production facility that is approximately 165,000 s.f., which includes space for its warehouse, office areas, manufacturing operations, and future expansion/special projects. The facility was purchased from a garment manufacturer and retrofitted to begin production of modular housing for the long-term rebuilding efforts in Louisiana after Hurricane Katrina. The facility is located on approximately 20 acres of land. LASB Homes currently operates with minimal automated equipment, but they are able to produce an average-sized 1,200 s.f. modular home. The maximum production capacity for this size home is equivalent to approximately 875 homes per year.

Modular House Design

The baseline home profiled in this chapter has a 1,600 s.f. floor plan, which complies with the state building code. The entire house is constructed in the plant facility, typically using 2x6 wood studs and commonly used residential construction materials. The house design, manufacturing plant process, quality program, and construction site installation are monitored by the appropriate state agency or a state-approved third party to ensure compliance with the building code. The final Modular Home State Certification label is attached to the house once the construction is complete and all tests and inspections have been performed successfully in the plant.

None of the typical building materials used have long lead times, but if specialty building products are specified or only one supplier is approved to provide a specific component or material, a shortage can be realized (especially during a major rebuilding effort). To avoid material supply issues, the managers of the production facility can do the following:

1. Establish design specifications that are based on performance criteria that meet the state building code and can be easily confirmed by the quality control department
2. Maximize the manufacturing supplier base by specifying commonly used building products, equipment, and materials
3. Enter into contract supplier agreements to ensure that disruptions or delays of critical components can be avoided

The production planner and purchasing manager must strategically identify those components that typically require the longest lead times and ensure that they do not become supply chain issues. Table 3-1 lists a sample of typical construction materials that have long lead times and should be planned for accordingly.

Table 3-1: Typical Construction Materials with Long Lead Times

In-Plant
Any specialty components
Trim and finishing materials
Windows or doors
Fixtures or accessories
HVAC equipment

Baseline Production Facility Characteristics

When possible, it is recommended that the production facility be located in an uncongested area—ideally, no farther than 15 miles from a major transportation route. The recommended physical dimensions of the production facility must include a minimum height clearance of 24 feet to accommodate cranes and the height of a finished house. The support columns require spacing of 80 l.f. between them. The facility will require a loading dock area with four doors measuring 20 feet in width to accommodate incoming material handling, and one door measuring 20 feet in width to accommodate outgoing shipments of finished modular housing units. The loading dock needs to accommodate tractor trailer carriers for transport of the modular units. A minimum overall production space of 100,000 s.f. is required. This overall space needs to be segmented into areas for: (1) receiving; (2) shipping; (3) staging raw materials and components; and (4) production. A warehouse area (approximately 35,000 s.f.) is also needed for material storage; this area can be part of the main production space or a separate building. Table 3-2 lists baseline production facility characteristics.

Table 3-2: Baseline Production Facility Characteristics

Item	Quantity	Comments
Floor plan space	100,000 s.f.	Manufacturing operations
Location	15 miles	Distance to nearest major transportation routes
Ceiling height	24 feet	To accommodate cranes and finished house height
Column spacing	80 l.f.	Distance needed to maneuver work-in-process (WIP)
Loading dock	5 bays	Five 20-ft wide doors: 4 for incoming, 1 for outbound
Departments	4 areas	Receiving, shipping, material staging, & production

Many existing vacant facilities may actually be well-suited for conversion to a modular housing production facility. These include facilities that were previously used to manufacture durable goods, automotive parts, textiles, warehouses, and factory-built housing. If such facilities are available, they can be evaluated to determine if the key production features exist or can be easily modified.

Physical Plant Utility Requirements

The production facility must include electrical, gas, septic/sewer, and water utilities. For the electrical, 480-volt, three-phase service is necessary in order to accommodate the electrical needs of typical tools and equipment used in a modular housing facility. An air-compressor system with a dryer is needed for power air tools (e.g., nail and screw guns). A waste disposal and recycling system must be established in order to limit the trash generated from raw material packaging and scrap lumber. Table 3-3 identifies utility services needed for the baseline modular housing facilities.

Table 3-3: Baseline Utility Requirement

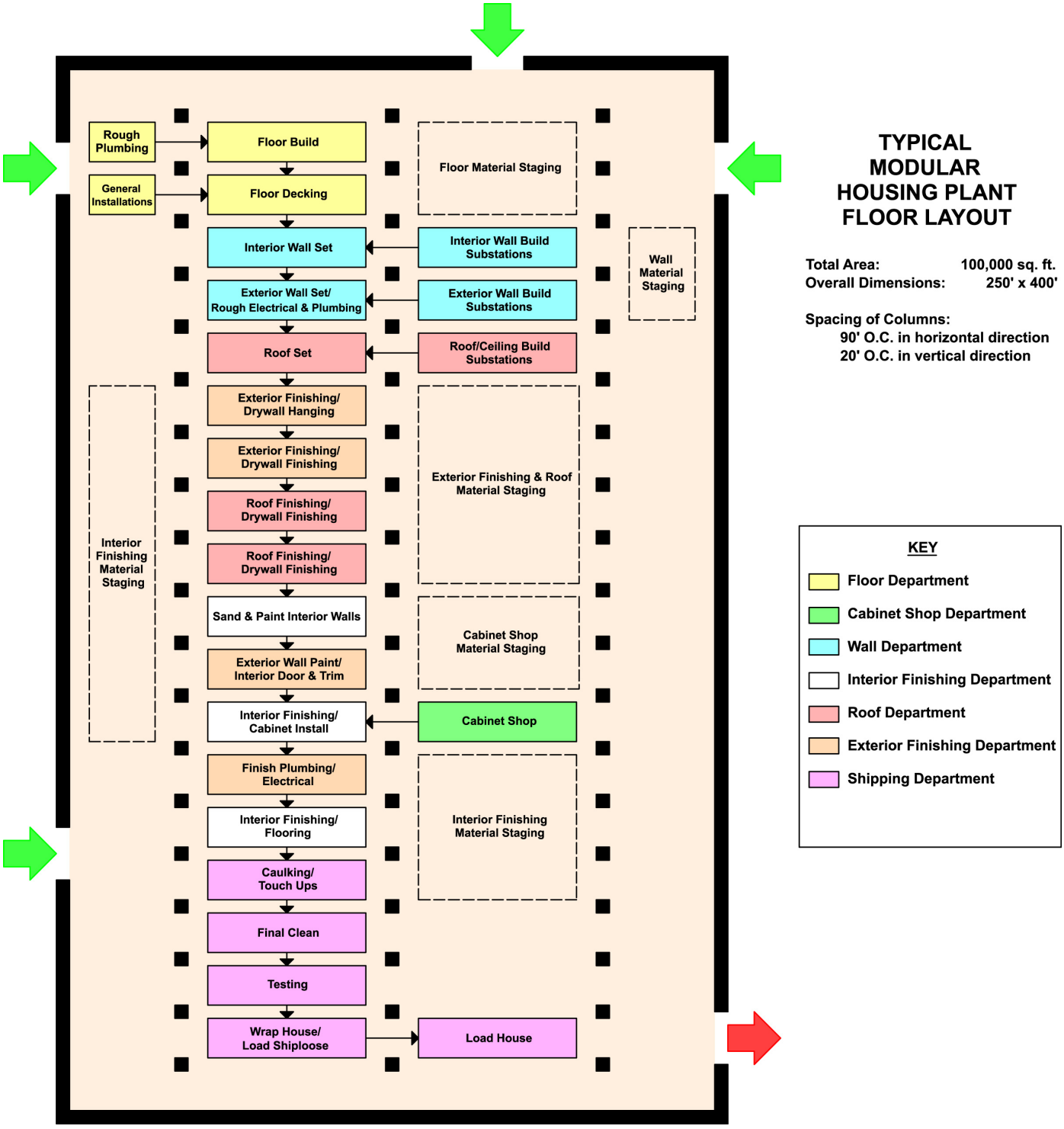
Utility	Capacity	Use
Electrical	1,500-amp	Equipment/tooling (480-volt/240-volt, 3-phase)
Gas	36 cu-ft/s.f.	Heating equipment (depends on climate needs)
Sewer/septic	76,000-gal/month	Cleaning/workers
Water	76,000-gal/month	Cleaning/workers

Production Floor Layout

A typical layout for a modular housing plant is either arranged in a shotgun or sidesaddle production line configuration. A shotgun configuration is arranged with dual parallel lines with modules indexing or flowing lengthwise. A sidesaddle configuration is arranged in a single line with transverse indexing or flow of modules as illustrated in Figure 3-1, which will serve as our baseline example. Other types of production line configurations are L-shaped, U-shaped, and almost every conceivable combination, depending on the shape and characteristics of the facility. For our baseline example, we will assume a total production space of 100,000 s.f.

The production layout in a modular housing plant has a main production line and subassembly stations that feed the main line. Activities required to produce modular housing are listed in Table 3-4 (see page 16).

Figure 3-1: Traditional Sidesaddle Configuration for Modular Housing Plant



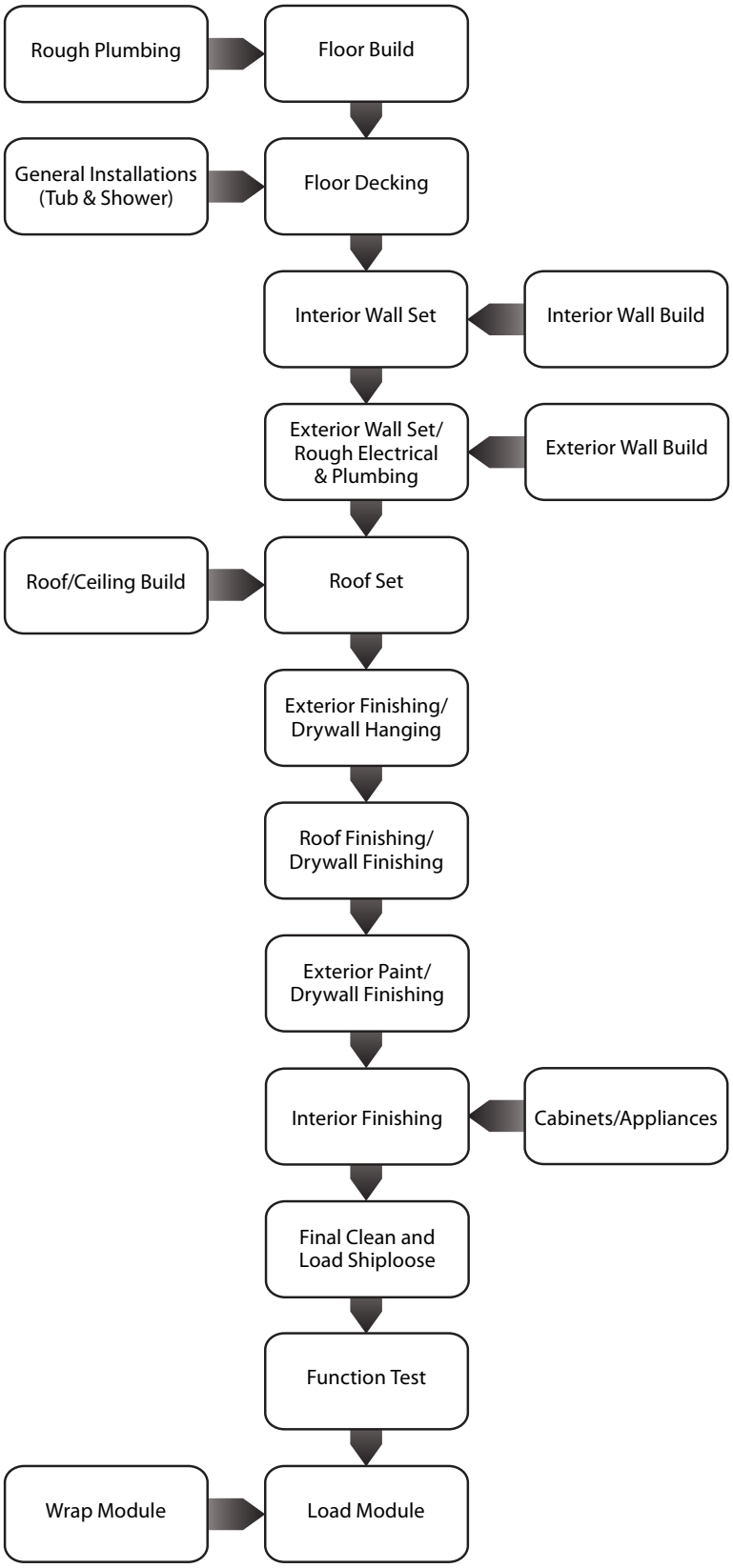
Existing commercial or industrial facilities can be adapted to allow for the baseline production, even if the final layout is a variation of Figure 3-1. The typical process flow is illustrated in Figure 3-2. A new facility can also be built to achieve the baseline production requirements. Furthermore, many facilities of existing modular housing units suppliers may actually vary significantly from Figure 3-1 depending upon the equipment selected, the degree of automation, and facility configuration. Photo 3-1 shows the Floor Build Area within LASB Homes.

Photo 3-1: Floor Build Area
Source: Louisiana Systems Built Homes

Table 3-4: Production Activities Required by Workstation

Department	Station Name	Location	Description of Station Tasks
Floor	General installations	Subassembly	Prep showers/toilets/tubs for installation
Floor	Rough plumbing	Subassembly	Prep rough plumbing line
Floor	Floor build	Main line	Frame floor and install rough plumbing
Floor	Floor decking	Main line	Insulate floor, install decking, and install showers/toilets/tubs
Cabinet shop	Cabinet shop	Subassembly	Assemble cabinets
Walls	Interior wall build	Subassembly	Build interior walls
Walls	Interior wall set	Main line	Set in place interior walls
Walls	Exterior wall build	Subassembly	Build exterior walls
Walls	Exterior wall set/rough elec & plumb	Main line	Set in place exterior walls
Roof	Roof/ceiling build	Subassembly	Roof frame/ducts/electrical wiring
Roof	Roof set	Main line	Install roof on unit
Exterior finishing	Exterior wall finishing/drywall hanging	Main line	Exterior insulation/install drywall
Exterior finishing	Exterior wall finishing/drywall finishing	Main line	Exterior sheathing/tape and 1st coat of mud and dry
Roof	Roof finishing/drywall finishing	Main line	2nd coat of mud and dry/install insulation and shingles
Roof	Roof finishing/drywall finishing	Main line	3rd coat of mud and dry/install shingles
Interior finishing	Sand & paint interior walls	Main line	Sand and paint interior walls
Exterior finishing	Exterior wall paint/interior door & trim	Main line	Paint exterior/install interior doors and trim
Interior finishing	Interior finishing/cabinet install	Main line	Install cabinets, vanity and countertops, and appliances
Exterior finishing	Finish plumbing and electrical	Main line	Install electrical/plumbing fixtures and outlets
Interior finishing	Interior finishing/flooring	Main line	Install carpet, tile, and/or hardwood
Interior finishing	Caulking and touch up	Main line	Caulking and touch-up painting
Shipping	Cleaning	Main line	Interior finishing and cleaning
Shipping	Testing	Main line	System testing
Shipping	Wrap/shiploose (furniture, etc.)	Main line	Wrap house and load shiploose—prep for shipping
Shipping	Load house	Main line/docking bay	Load house on carrier

Figure 3-2: Typical Modular Housing Plant Process Flow



Tooling Requirements

The typical modular housing production facility has some automation, but much of the construction work can also be done manually. Some housing components, such as roof trusses, arrive at the plant as purchased, pre-assembled parts rather than being built at the plant. Much of the tooling is for woodworking, steel fabrication, carpentry, and a wide range of department-specific tasks.

The baseline plant must have typical tooling and equipment for transport and material handling, which includes dollies, fork trucks, cranes, and lifts. Tables 3-5 through 3-11 list the tools and equipment required for use within the production facility. All costs were sourced in March 2010.

Table 3-5: Tools and Equipment for the Floor Department

Location of Usage	Quantity	Market Price	Subtotal Cost
Floor jig	1	$9,000	$9,000
Sabre saw	4	$250	$1,000
Reciprocating saw	2	$250	$500
Beam saw	1	$150 [a]	$150
Miter/radial-arm saw	2	$450	$900
Lumber cart with flip deck	1	$21,000	$21,000
Air compressor pump	1	$9,000	$9,000
Impact wrench	2	$200	$400
Nail gun	6	$250	$1,500
Drill	4	$100	$400
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
2-ton crane with bridge rails	1	$120,000	$120,000
Total Cost			**$198,850**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 3-6: Tools and Equipment for the Cabinet Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Miter/radial-arm saw	2	$450	$900
Chop saw	3	$400	$1,200
Table saw (saw stop, 14 inch)	1	$4,200	$4,200
Hot-melt glue system	1	$3,500	$3,500
Face-framing machine (drill)	1	$11,500	$11,500
Router	3	$100	$300
Belt sander	1	$1,000 [a]	$1,000
Clamp	5	$20	$100
Brad gun	2	$250	$500
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
Total Cost			**$58,200**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 3-7: Tools and Equipment for the Wall Department

Location of Usage	Quantity	Market Price	Subtotal Cost
1-ton crane with bridge rails	2	$110,000	$110,000
Sabre saw	2	$250	$500
Miter/radial-arm saw	1	$450	$450
Reciprocating saw	1	$250	$250
Cordless drill	3	$100	$300
Router (1.5 hp)	2	$100	$200
Nail gun	7	$1,750	$1,750
Total Cost			**$113,450**

Table 3-8: Tools and Equipment for the Interior Finishing Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Miter/radial-arm saw	2	$450	$900
Texture sprayer	1	$8,000	$8,000
Air compressor pump	1	$5,000	$5,000
Push cart	1	$6,500	$6,500
Router	3	$100	$300
Ames mud-tool set	1	$4,000	$4,000
Sander	2	$400	$800
Carpet stretcher	1	$150 [a]	$150
Wet saw	1	$4,300 [b]	$4,300
Miter/radial-arm saw	2	$450	$900
Nail gun	2	$250	$500
Total Cost			**$31,350**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 3-9: Tools and Equipment for the Roof Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
4-ton crane with bridge rails	1	$160,000	$160,000
OSB decking monorails	2	$25,000	$50,000
Scaffold system	1	$140,000 [a]	$140,000
Miter/radial-arm saw	2	$450	$900
Table saw	1	$4,500	$4,500
Sabre saw	4	$250	$1,000
Reciprocating saw	1	$250	$250
Nail gun	5	$250	$1,250
Ceiling spray equipment	1	$25,000	$25,000
Safety harness, strap, & cable	2	$5,500	$11,000
Total Cost			**$393,300**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 3-10: Tools and Equipment for the Exterior Finishing Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Metal hand brake (14 inch)	1	$6,500	$6,500
Table saw	1	$4,500	$4,500
Miter/radial-arm saw	2	$450	$900
Sabre saw	2	$250	$500
Nail gun	3	$250	$750
Total Cost			**$13,150**

Table 3-11: Tools and Equipment for the Shipping Department

Location of Usage	Quantity	Market Price	Subtotal Cost
Di-electric tester	3	$1,500	$4,500
Circuit continuity tester	8	$25	$200
Breaker test/torque screwdriver	4	$250	$1,000
Air & water test/100-psi pressure gauge	4	$25	$100
Gas tester/mercury manometer	2	$90	$180
HVAC duct-blaster kit	1	$1,500	$1,500
Ladder	4	$150 [a]	$600
Nail gun	7	$250	$1,750
Diesel forklift (8,000 lbs)	2	$35,000	$70,000
Hydraulic lifter	6	$9,000	$54,000
Transport carriers	6	$7,000	$42,000
Trucks (pre-owned)	4	$50,000 [b]	$200,000
Total Cost			**$375,830**

For cost details about superscripts "a" through "g" please see the Appendix.

Labor Requirements

Generally, given the specific construction requirements of modular housing, the baseline plant assumes that plant supervisors have some experience producing modular homes. This experience is essential to ensure that quality and construction practices are followed to meet the state building code. Although the construction labor does not require specialized training, the baseline skill sets required include the ability to read a tape measure and drawings/blueprints, and work with residential construction tools and equipment. The general construction labor is classified as "direct labor" for the production of modular housing. Table 3-12 lists the direct labor requirements and typical hourly rates for each type of trade based on Occupational Employment Statistics for the Residential Construction Industry (2008).

Table 3-12: Baseline Direct Labor Requirements

Direct Labor Trade Type	Quantity of Labor Needed	Labor Rates
Carpenter	36	$19.71/hr
Cabinet maker	3	$18.11/hr
Carpenter helper	7	$12.47/hr
Plumber	5	$22.74/hr
Drywall installer	6	$19.02/hr
Drywall taper	3	$23.17/hr
Drywall finisher	8	$19.34/hr
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Indirect Labor	Average Annual Salary
General manager	$150,000
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The estimated annual total labor cost for the baseline modular plant is summarized in Table 3-14. The actual labor cost will vary based on the location of the plant and the skill level of the workers.

Table 3-14: Summary of Total Labor Costs

Labor Type	Total Labor Cost
Direct labor	$4,070,684
Indirect labor	$591,000
Overall Total Labor	**$4,661,684**

Key Labor Functions within the Facility

The general manager, production/plant manager, and/or a planner generate and manage the production schedule at the facility. The people in these positions should have experience in modular housing facilities because compliance with the state building code-approved systems is critical to the successful production of modular housing. The purchasing manager is responsible for establishing and maintaining strong partnerships with suppliers, vendors, and subcontractors. Finally, functional-area supervisors, in coordination with the production manager, plan ahead and prioritize material replenishment based on production.

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Critical Construction Items when Producing Modular Housing

Material supply issues and shortages can be minimized by identifying and establishing relationships with suppliers located within 500 miles of the production facility, by entering into supply agreements with multiple sources, and by maintaining inventory lead times of three to four days. The plant must also maintain alternative suppliers that can meet the state building code specifications. This is critical for components such as doors, windows, and roofing parts.

Managing the flow of material throughout the plant is critical to the timely production of houses. Keeping a minimum supply of material on the production line and planning for the houses that will be produced well in advance of the actual production are recommended. Additional staging space will be necessary on the production line, so the layout will be important to minimize the chances of bottlenecks. The purchasing manager should have knowledge of modular housing products, and at least one year of experience working in a modular housing plant.

Production Capacity Strategies

The baseline production capacity for the modular housing facility assumes a single shift at 40 hours per work week. The daily production schedule can be arranged as the management sees fit; it could be a typical 8-hour, 5-day-a-week schedule or another variation on a 40-hour week schedule. Generally, the schedule will conform to the labor availability and production requirements.

Production capacity can be increased by:

1. Changing from the standard 40-hour week to a 60-hour week (e.g., 12-hour, 5-day-a-week schedule). Typically, a manufacturer may prefer this approach before committing to a full second shift.
2. Adding a second shift (which will require additional labor). If this is to be done, the plant must have access to additional construction labor and management in the vicinity. Generally, the labor bottleneck will be the management and professional staff, not the general construction labor. For a multiple-shift strategy to be successful, the planning and construction procedures must be well defined and executed because the second shift will need to continue in a "seamless" manner the work that was started by the first shift.

Achieving the maximum production capacity will typically involve additional labor beyond a single shift. Three production capacity scenarios are provided in this chapter that can be considered based on the production needs of the jurisdiction that is rebuilding. See Table 3-15 (page 22) for the production capacity options based on a 1,600 s.f. house design.

Table 3-15: Production Capacity Scaling Options

Strategy	Direct Labor	Equipment/Automation Level	Production Capacity
Baseline (1 Shift)	116	Low	7 houses/week 350 houses/year
Baseline (1 Shift w/OT)	116	Low	10 houses/week 500 houses/year
Increase labor size (2 Shifts)	195	Low	14 houses/week 700 houses/year

Transport and Installation Requirements

For the baseline condition, the modular house is transported from the plant to the jobsite where it is installed on a permanent foundation. It is essential to coordinate the installation with local building code officials because inspections of the foundation and the installation process will be necessary. A crew consisting of one crane operator and three to six setters should be able to install a typical 1,600-s.f. house during an eight-hour shift. A 20-ton jack and two translift crawlers are normally used as part of the installation process. Some installers rely on a crane alone to lift and set units in place. Nonetheless, subcontractors must first perform approximately $10,000 worth of site preparation/demolition, sewer and drainage installation, and a 200-amp electrical-service installation.

The entire set-up process can be subcontracted to a licensed builder. Regardless of who performs the set up, a set-up inspection is required by the state agency (or a state-approved third party) prior to the issuance of a Certificate of Occupancy.

Table 3-16 lists the tools and equipment required for set up, followed by Table 3-17, which lists the direct labor required for set up.

Table 3-16: Tools and Equipment Required for Installation at the Jobsite

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Crane (rented)	1	$1,200 per hour	$9,600
Generator	1	$5,495 [a]	$5,495
Air compressor	1	$2,300 [b]	$2,300
Sabre saw	2	$100	$200
Sledge hammer	2	$66 [c]	$132
Reciprocating saw	1	$250	$250
Level and tape measure	3	$25 [d]	$75
String line and chalk line	3	$30 [e]	$90
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
Hand trucks	1	$100 [f]	$100
Chainsaw	2	$200 each [g]	$400
½-hp router	2	$100 each	$200
Chop saw	2	$400 each	$800
Cordless drill	2	$100 each	$200
Total Cost			**$54,842**

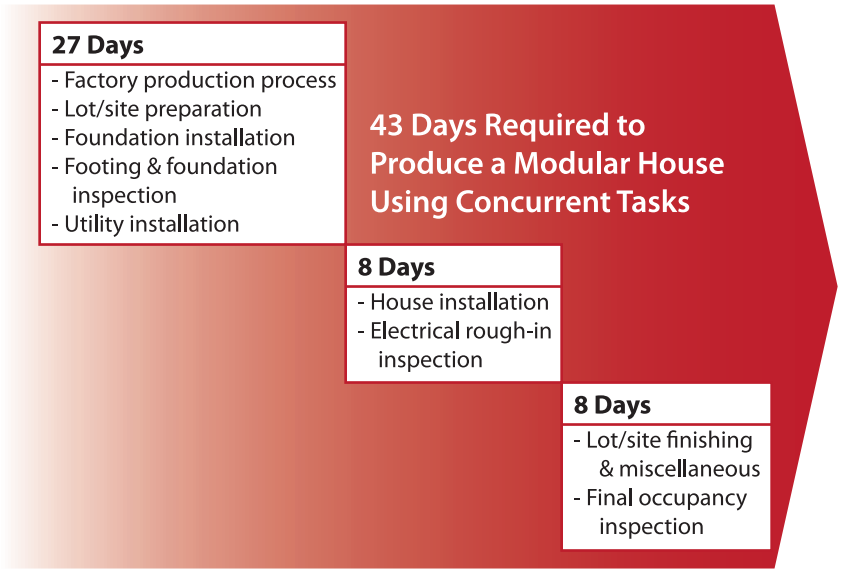
For cost details about superscripts "a" through "g" please see the Appendix.

Table 3-17: Direct Labor Required for Installation at the Jobsite

Direct Labor	Quantity	Labor Rates
Crane operator	1	$23.75/hr
Home installer	4	$15.09/hr
Electrician	1	$22.22/hr
Plumber	1	$22.74/hr
HVAC installer	1	$19.64/hr

Figure 3-3 graphically shows that if concurrent tasks are scheduled and executed where possible, then the time to produce and install a modular house can be compressed to 43 days. This includes the complete process for in-house (factory) production and jobsite installation. An average of one 1,600 s.f. modular house can be produced during approximately 10 days of the in-house production process, which does not include queuing time for scheduling its production. The jobsite time requires approximately six weeks from site preparation to installation of this size house, which does not include delays related to items such as weather or inspections. If concurrent activities are *not* executed, such as beginning production of a house at the plant while conducting site-preparation activities (for the same house), then the total sequential production schedule could expand to as many as 52 days to produce a house this size once the order has been received and the house enters the production process.

Figure 3-3: Total Compressed Time Required to Produce and Install a Modular House



4 Panelized Housing

Technical Approach

This chapter defines the typical panelized production facility based on a general overview of the manufacturing practices at Forest Homes (a whole-house panelized building-system manufacturer in central Pennsylvania) and basic industrial engineering principles. This characterization of the typical panelized production facility is meant to establish a baseline for manufacturing requirements needed to produce a typical 1,600 s.f. house floor plan. These requirements should be considered as benchmarks for: (1) vetting existing manufacturers of whole-house panelized production; and (2) providing guidance for the decision to operate a typical panelized housing production facility.

It should be noted that the descriptions within this chapter do not fully capture all the production details of Forest Homes simply because its facility exceeds many of the baseline benchmarks in terms of the size of their facility and automated production equipment used. For the baseline panelized production facility example represented in this chapter, the production layout and equipment specifications have been optimized to represent the minimum requirements—cost, facility size, equipment, and labor needs.

In fact, the Forest Homes production facility is 138,000 s.f., which includes space for its warehouse, office areas, and manufacturing operations. This is much larger than the representative baseline presented here. The construction costs to build this facility, excluding the price of land, tractors, and trailers, amounted to approximately $2.7 million. The production facility is situated on 11 acres and is highly automated with Computer-Numerically Controlled (CNC) equipment. Using high-tech equipment, Forest Homes is able to produce an average size home of 2,157 s.f. The maximum production capacity is one-million s.f. of housing, which equals approximately 463 average-sized homes (2,157 s.f.) for Forest Homes annually.

Panelized House Design

The baseline home profiled in this chapter has a 1,600 s.f. floor plan. It is constructed of light wood frame and drywall panels. The roof is constructed of pre-assembled trusses. The wall panels and roof trusses are built in the plant and shipped to the jobsite. The roof trusses are inspected in the plant and labeled in accordance with the state and local building code official requirements. The panels are shipped "open" because the local building code official must conduct inspections at the jobsite, after plumbing and electrical installation are completed. After the panels are approved, they are "closed in" with drywall. The panelized manufacturer schedules a second delivery to have exterior finishing materials (e.g., sheathing, roofing) and interior finishing materials (e.g., cabinets, toilets, plumbing and electrical fixtures, and flooring) delivered to the jobsite so that subcontractors and inspectors can complete the final construction and inspection of the home.

Table 4-1 (see page 25) lists a sampling of typical construction materials used in panelized housing. None of the typical building materials has a long lead time, but material supply shortages can occur for a variety of reasons. By creating thoughtful, strategic contract agreements with suppliers, a panelized production facility can avoid disruptions or delays involving critical material components. Since panel construction primarily relies on wood materials, special supplier agreements can be arranged with Oriented Strand Board (OSB) and lumber manufacturers to better ensure a consistent supply of these critical components.

Table 4-1: Typical Construction Materials with Long Lead Times

In-Plant
Roofing shingles/ridge vent
Siding/trim
Flooring products
Specialty bath/kitchen fixtures
HVAC equipment

Baseline Production Facility Characteristics

When possible, it is recommended that the production facility be located in an uncongested area—ideally, no farther than 15 miles from a major transportation route. The recommended physical dimensions of the production facility must include a height clearance of at least 18 feet to accommodate a lift for overhead trolleys. The support columns require spacing of 30 l.f. between them. The facility will require a loading dock area with four doors measuring 20 feet wide and 14 feet high to accommodate incoming material handling, and one door measuring 20 feet wide and 14 feet high to accommodate outgoing shipments of finished panel and roof truss units. The loading dock needs to accommodate tractor trailer carriers for transport of the panels and roof trusses. For ease of loading, it is recommended that the loading dock be four feet lower than the production floor. A minimum overall production space of 62,500 s.f. is required, and should be segmented into areas for: (1) receiving; (2) shipping; (3) staging for raw materials and components; and (4) production. A warehouse area (approximately 35,000 s.f.) is also needed for material storage; this area can be part of the main production space or a separate building. Table 4-2 lists baseline production facility characteristics.

Many existing vacant facilities may actually be well-suited for conversion to a panelized production facility.

Table 4-2: Baseline Production Facility Characteristics

Item	Quantity	Comments
Floor plan space	62,500 s.f.	Manufacturing operations
Location	15 miles	Distance to nearest major transportation routes
Ceiling height	18 feet	To accommodate lifts for overhead crane trolleys
Column spacing	80 l.f.	Distance needed to maneuver work-in-process (WIP)
Loading dock	4 bays	Five 20-ft wide doors: 4 for incoming, 1 for outbound (4 ft lower than production floor)
Departments	4 areas	Receiving, shipping, staging, & production

These include facilities that were previously used to manufacture durable goods, automotive parts, textiles, warehouses, and factory-built housing. If such facilities are available, they can be evaluated to determine if the key production facility characteristics exist or can be easily modified.

Physical Plant Utility Requirements

The production facility must include electrical, gas, septic/sewer, and water utilities. For the electrical, 480-volt, three-phase service is necessary in order to accommodate the electrical needs of typical tools and equipment used in a panelized production facility. An air compressor system with a dryer is needed for power air tools (e.g., nail guns). A waste disposal and recycling system must be established in order to limit the trash generated from raw material packaging and scrap lumber. Table 4-3 identifies utility services needed for a baseline panelized production facility.

Table 4-3: Baseline Utility Requirements

Utility	Capacity	Use
Electrical	1,600-amp	Equipment/tooling (480-volt/240-volt, 3-phase)
Gas	36 cu-ft/s.f.	Heating equipment (depends on climate needs)
Water	25,000-gal/month	Cleaning/workers
Sewer/septic	25,000-gal/month	Cleaning/workers

Production Floor Layout

The main production activities required to manufacture a panel are listed in Table 4-4. Photo 4-1 shows the wall assembly to the right and truss build-up station to the left within the Forest Homes plant.

The overall plant layout of the baseline panelized production facility is presented in Figure 4-1. Existing commercial or industrial facilities can be adapted to allow for the baseline production, even if the final layout is a variation of Figure 4-1 (see page 27). A new facility can also be built to achieve the baseline production requirements. The facilities of many existing panelized whole-house unit suppliers may actually vary significantly from Figure 4-1 depending upon the equipment selected and the degree of automation that is used. The typical process flow is illustrated in Figure 4-2 (see page 28).

Photo 4-1: Wall Assembly and Truss Table
Source: Forest Homes

Tooling Requirements

Table 4-4: Production Activities Required by Workstation

Department	Station Name	Location	Description of Station Tasks
Walls	CAD/CAM station	Main line	Panel layout for CAD/CAM programming of CNC equipment
Walls	Lumber cutting (saw)	Main line	Cutting lumber for all panels
Walls	Milling/cutting	Main line	Prepare studs for walls
Walls	Sloped/gable wall build	Subassembly	Layout lumber, fasten studs & sheathing
Walls	Wall build	Main line	Layout lumber, fasten studs
Walls	Window/door build	Subassembly	Assemble windows & doors
Walls	Window/door installation	Main line	Install windows & doors into the walls
Walls	Rough electrical	Main line	Pre-drills for electrical
Walls	Stairs build up	Subassembly	Cut lumber, route risers, & fasten treads
Roof	Truss preparation	Main line	Cut lumber for trusses
Roof	Truss build/third-party inspection	Main line	Layout lumber, assemble trusses, and 3rd party inspection
Roof	Truss bundles	Main line	Bundle trusses for shipping
Floor	Floor preparation	Main line	Cut lumber for floors
Floor	Floor build	Main line	Layout lumber and assemble floors
Shipping	Load into transport carrier	Main line/ docking bay	Load panels and bundled materials on carrier

Figure 4-1: Typical Panelized Housing Plant

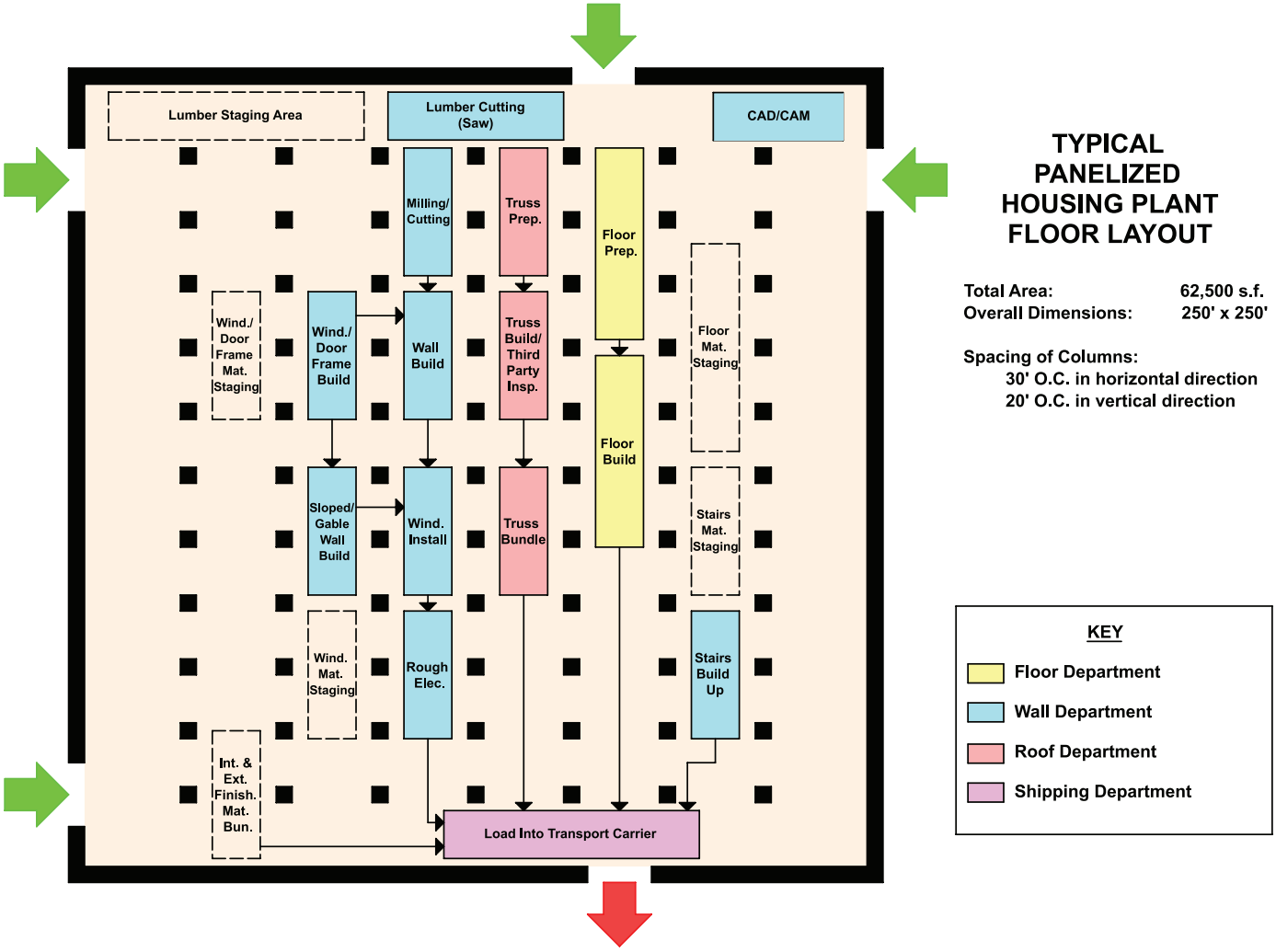
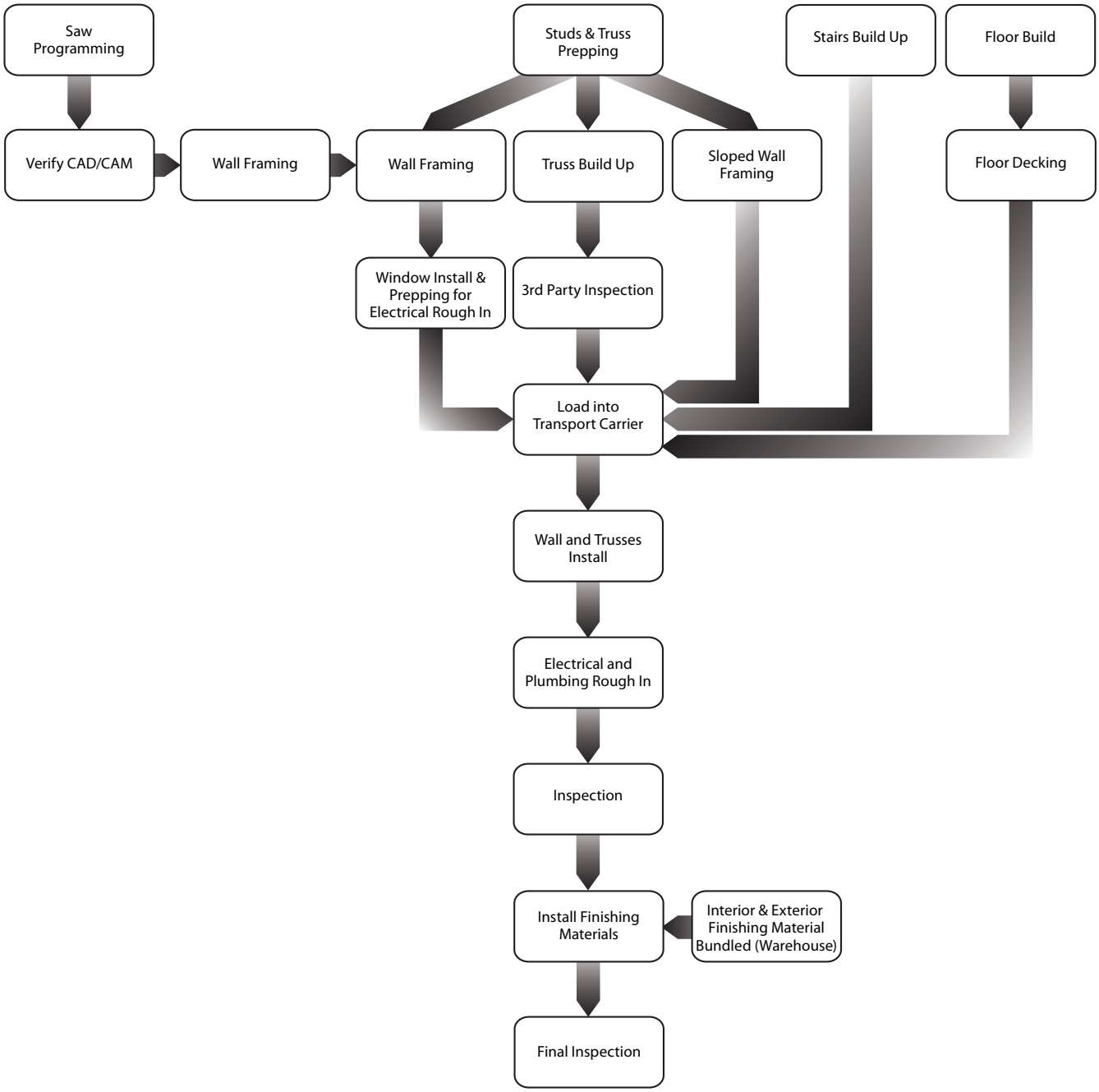


Figure 4-2: Typical Panelized Whole-House Plant Process Flow



The typical whole-house panelized production facility has moderate automation, including equipment to build roof trusses. Trusses should be pre-cut using a linear saw and then assembled manually. These components require in-house inspection by a building code-authorized third party. Most tooling is not automated, but it is the typical equipment found in most manufacturing facilities that transport and fabricate wood-based materials. Nonetheless, the CNC equipment and assembly tables are essential to rapid production with a small plant labor force.

Several dollies are needed to transport raw material (e.g., studs and pre-cut lumber), while a forklift is needed to transport material from the warehouse to the production floor. However, it is recommended that assembled walls, floors, and trusses be transported using a half-ton (minimum) overhead crane with straps and a spreader bar. Tables 4-5 through 4-8 list the tools and equipment required for use within the production facility. All costs were sourced in March 2010.

Labor Requirements

Table 4-5: Tools and Equipment for the Wall Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Compressor	1	$28,000	$28,000
CNC wall-stud saw	1	$140,000 [a]	$140,000
Wall-panel table	1	$400,000 [b]	$400,000
Table saw (14 inch)	1	$4,200	$4,200
Sabre saw	3	$100	$300
Reciprocating saw	1	$250	$250
Router (1.5 hp)	2	$100	$200
Diesel forklift (8,000 lbs)	1	$35,000	$35,000
Chop saw	2	$400	$800
Cordless drill	2	$100	$200
Total Cost			**$608,950**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 4-6: Tools and Equipment for the Truss Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
CNC roof-truss saw	1	$200,000 [a]	$200,000
Roof-truss table	1	$400,000	$400,000
Radial-arm saw	1	$15,000	$15,000
Sabre saw	2	$100	$200
Reciprocating saw	1	$250	$250
Chop saw	1	$400	$400
Cordless drill	1	$100	$100
Rafter saw	1	$250	$250
Total Cost			**$616,200**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 4-7: Tools and Equipment for the Floor Department

Location of Usage	Quantity	Market Price	Subtotal Cost
Floor jig	1	$25,000	$25,000
Sabre saw	4	$250	$1,000
Reciprocating saw	2	$250	$500
Beam saw	1	$150 [a]	$150
Miter/radial-arm saw	2	$450	$900
Nail gun	6	$250	$1,500
Drill	4	$100	$400
Overhead trolley (2-ton)	1	$38,000	$38,000
Total Cost			**$67,450**

For cost details about superscripts "a" through "g" please see the Appendix.

Table 4-8: Tools and Equipment for the Shipping Department

Tools and Equipment	Quantity	Market Price	Subtotal Cost
½-ton crane, bridge rails, straps, & spreader bar	2	$75,000	$150,000
Custom transport carrier	24	$18,000	$432,000
Truck extender frames for floors	8	$15,000	$120,000
Trucks (pre-owned)	4	$50,000 [a]	$200,000
Total Cost			**$902,000**

For cost details about superscripts "a" through "g" please see the Appendix.

The construction labor required to build a whole-house panelized house is very similar to that used for site-built construction. Specialized training is not required, but CNC equipment operators will need some additional training beyond that of the typical saw operator. The baseline skill sets required include the ability to read a tape measure and drawings/blueprints, and work with residential construction tools and equipment. The general construction labor is classified as "direct labor" in the manufacture of panelized whole-house units. Table 4-9 lists the direct labor requirements and hourly rates.

Table 4-9: Baseline Direct Labor Requirements

Direct Labor Trade Type	Quantity of Labor Needed	Labor Rates
Carpenter	4	$19.71/hr
Carpenter helper	5	$12.47/hr
Router operator	1	$19.71/hr
Saw operator	1	$18.11/hr
Warehouse worker	1	$12.71/hr
Forklift driver	2	$15.85/hr
Truck driver	3	$18.35/hr
General construction helper	2	$12.71/hr

Equally essential to the manufacture of a panelized whole-house unit are the management and professional staff. The management, engineering, quality, accounting, marketing, purchasing, and human resources staff are classified as "indirect labor." Table 4-10 lists the indirect labor requirements and approximate annual salary considerations.

Table 4-10: Baseline Indirect Labor Requirements

Indirect Labor	Average Annual Salary
General manager	$150,000
CFO	$85,000
HR director	$65,000
Accounts payable and receivable	$36,000
Purchasing manager	$65,000
Operations clerk	$45,000
Engineering manager/QA	$80,000
Production/plant manager	$65,000

The estimated total labor cost for the baseline modular plant is summarized in Table 4-11. The actual labor cost will vary based on the location of the plant and the skill level of the workers.

Table 4-11: Summary of Total Labor Costs

Labor Type	Total Labor Cost
Direct labor	$632,091
Indirect labor	$591,000
Overall Total Labor	**$1,223,091**

Key Labor Functions within the Facility

The general manager, production/plant manager, and/or a planner generate and manage the production schedule at the facility while also orchestrating the work of subcontractors at the jobsite. This provides more central control over the project and better estimates of when to deliver the finishing materials. The purchasing manager is responsible for establishing and maintaining strong partnerships with suppliers, vendors, and subcontractors. Finally, functional-area supervisors, in coordination with the production manager, plan ahead and prioritize material replenishment based on production. This chain of communication is used also to communicate daily production expectations to direct labor personnel.

Inspections and the Quality Assurance Program

Although the roof truss fabrication is the only element that requires a third-party inspection and approval in the baseline panelized facility, a quality assurance program must be developed and implemented to ensure that all panels are manufactured in a consistent, high-quality manner. The engineering staff will typically define the performance specifications and inspection protocol, while the quality staff will perform the actual inspections of components and finished goods. If defects are discovered during production, mandatory rework is typically performed at the work station in which the defect is found. In all cases, the plant must develop a corrective action procedure that may include discarding defective components that cannot be adequately reworked.

Since the wall panels are manufactured as "open-assembly" components, the building code inspections are performed on the construction site by the local building code inspector—just like site-built construction. It is critical to have some staff in the plant who are familiar with the residential construction permitting and

inspection processes. This provides for better coordination and expectations of field installations between those that must deliver the panels and the building inspectors who must inspect the panels.

Critical Items when Manufacturing Whole-House Panelized Building Systems

The wall production and truss operations must be closely coordinated because a set of trusses and walls for a single house must be completed simultaneously for transport to the jobsite (i.e., to load and deliver in the correct order). In addition to random third-party inspections of wall panels, each production station, including the shipping department, must inspect the panels by using a "traveler" quality assurance checklist to ensure that the correct number of walls and trusses are placed in each truck. Wall panels and trusses must be labeled (e.g., using letters for interior walls and numbers for exterior walls). The jobsite crane operator must be provided with a sequence for assembling panels on site. Some components, such as gable walls, which typically require some custom design depending upon the roof design, must be assembled off the main production line. Provisions should be made in the plant layout for these components.

Production Capacity Strategies

The baseline production capacity for the panelized production facility assumes a single-shift at 40 hours per work week. The daily production schedule can be arranged as the management sees fit; it could be a typical 8-hour, 5-day-per-week schedule, or a 10-hour, 4-day-per-week schedule. Generally the schedule will be driven by the labor availability and production requirements.

Production capacity can be increased by adding a second shift (which will require additional labor). If this is to be done, the plant must have access to additional construction labor and management in the vicinity. Generally, the labor bottleneck will be the management and professional staff, not the general construction labor. For a multiple-shift strategy to be successful, the planning and construction procedures must be well defined.

Achieving the maximum production capacity will require additional equipment and labor beyond a single shift. This chapter describes three production capacity scenarios that can be considered based on the production needs of the jurisdiction that is rebuilding. See Table 4-12 for the production capacity options based on a 1,600 s.f. house design.

Table 4-12: Production Capacity Scaling Options

Strategy	Direct Labor	Equipment/Automation Level	Production Capacity
Baseline (1 Shift)	19	Medium	330,000 s.f./year 208 houses/year
Increase labor (2 Shifts)	38	Medium	660,000 s.f./year 412 houses/year
Increase labor (3 Shifts)	57	Medium	1,000,000 s.f./year 625 houses/year

Transport and Installation Requirements

For the baseline condition, a truck driver makes the first delivery consisting of wall panels, floors, and trusses, which must be transported on a custom-designed, house-carrier truck. The floors are installed on the foundation, and all necessary structural blocking and adjustments are made. A crane operator will hoist the house panels into place using a half-ton crane. Wall and truss installation are completed using a five-member carpentry crew, as well as subcontracted plumbers and electricians. This composition allows for a house to be set in less than one day if critical issues are coordinated, including space to deliver the panels, space for the crane, and no obstruction by electrical power lines.

After subcontractors install the "rough-in" plumbing and electrical, inspections are conducted by local building code officials, using either the International Building Code or the International Residential Code. The walls are then "closed in" with drywall, and a second delivery consisting of finishing components (e.g., flooring, cabinets, trim, and exterior sheathing) is coordinated by the plant. The size of the installation site crew needed to complete the house is significant. Table 4-13 lists the tools and equipment required for set up, followed by Table 4-14, which lists the direct labor required for completion of the house construction.

Table 4-13: Tools and Equipment for Installing/ Setting the House at the Jobsite

Tools and Equipment	Quantity	Market Price	Subtotal Cost
Crane (rented)	1	$1,200 per hour	$9,600
Generator	1	$5,495 [a]	$5,495
Air compressor	1	$2,300 [b]	$2,300
Sabre saw	3	$100	$300
Sledge hammer	3	$66 [c]	$198
Reciprocating saw	1	$250	$250
Level and tape measure	3	$25 [d]	$75
String line and chalk line	3	$30 [e]	$90
Hand truck	3	$100 [f]	$300
Chainsaw	5	$200 each [g]	$1,000
½-hp router	2	$100 each	$200
Chop saw	3	$400 each	$1,200
Cordless drill	2	$100 each	$200
Total Cost			**$21,208**

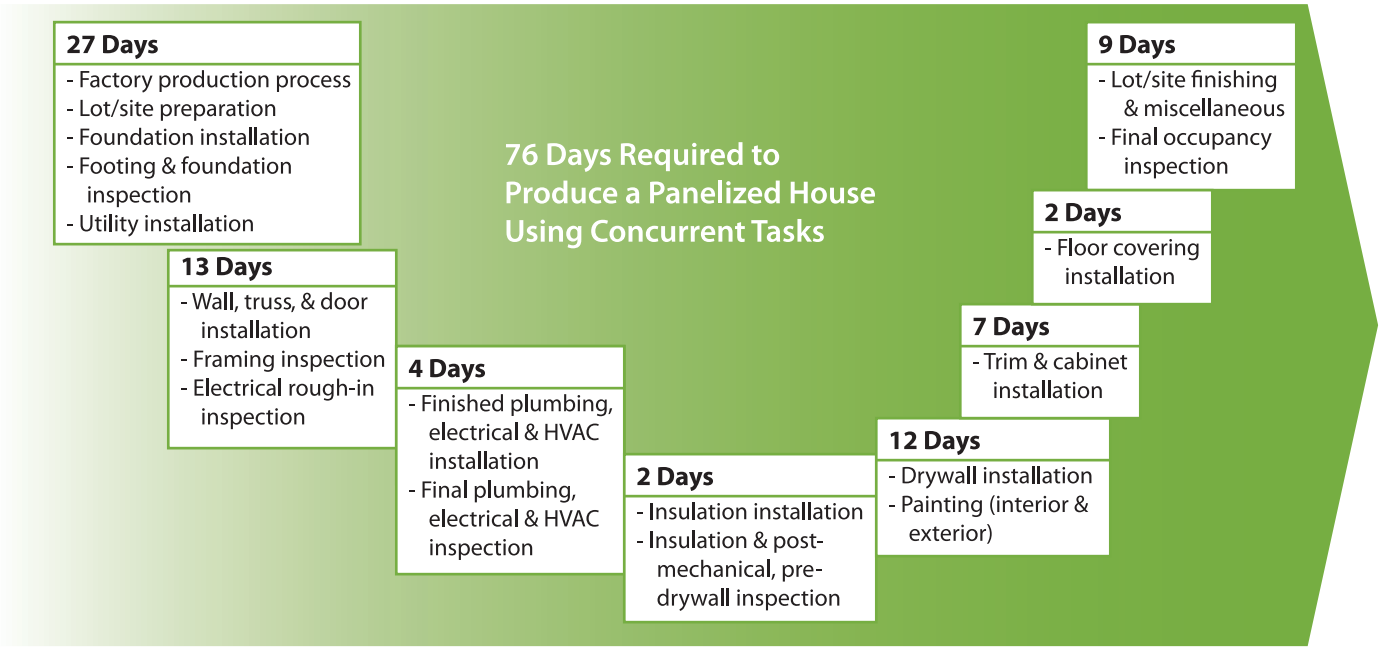
For cost details about superscripts "a" through "g" please see the Appendix.

Table 4-14: Direct Labor Required for Installation at the Jobsite

Direct Labor Trade Type	Quantity of Labor Needed	Labor Rates
Crane operator	1	$23.75/hr
Set-up installer	4	$15.09/hr
Electrician	1	$22.22/hr
Electrician helper	2	$12.81/hr
Plumber	2	$22.74/hr
Drywall installer	2	$19.02/hr
Drywall taper	1	$23.17/hr
Drywall finisher	2	$19.34/hr
Painter	2	$16.21/hr
Tile setter	1	$19.5/hr
Roofer	3	$15.91/hr
Exterior finisher	3	$20.18/hr
HVAC installer	1	$19.64/hr
General construction helper	2	$12.71/hr

Figure 4-3 graphically shows that if concurrent tasks are scheduled and executed where possible, then the time to produce and install a panelized house can be compressed to 76 days. This includes the complete process for in-house (factory) production and jobsite installation. An average of one 1,600 s.f. panelized house's components can be produced during one day of the in-house production process, which does not include queuing time for scheduling its production. The jobsite time requires approximately six weeks from site preparation to installation of this size house, which does not include delays related to items such as weather or inspections. If concurrent activities are *not* executed, such as beginning production of a house at the plant while conducting site-preparation activities (for the same house), then the total sequential production schedule could expand to as many as 83 days to produce a house this size once the order has been received and the house enters the production process.

Figure 4-3: Total Compressed Time Required to Produce and Install a Panelized House



Appendix A: **Assessment of Existing Factory-Built Plants**

Worksheet: Assessment of Existing Factory-Built Plants (1 of 2)

This worksheet can be used to provide a preliminary overview of an existing plant's capabilities and services, such that the local jurisdiction can plan accordingly.

Company Name: _____

Company Contact: _____

Address: _____

Phone: _____

1. Company's product line (check all that apply)

a. Architectural style:

- ❑ Ranches
- ❑ Victorian
- ❑ Cape Cods
- ❑ Two-Story Homes
- ❑ Other _____

b. Home size offered (check all that apply)

- ❑ Less than 1,000 s.f.
- ❑ 1,000 to 2,000 s.f.
- ❑ More than 2,000 s.f.

c. What is the average size house currently produced (in s.f.)?
Avg. house size _____

2. Current maximum production capacity (check one):

- ❑ Less than 5 homes per week
- ❑ 5 to 10 homes per week
- ❑ 11 to 20 homes per week
- ❑ More than 20 homes per week

3. Company's facility:

a. Location—distance of the facility from major highway

- ❑ Less than 10 miles
- ❑ 10 to 20 miles
- ❑ More than 20 miles

b. Plant size

- ❑ 30,000 to 50,000 s.f.
- ❑ 50,000 to 100,000 s.f.
- ❑ More than 100,000 s.f.

4. Company's equipment:

a. Level of automation or equipment (check one).

- ❑ Low
- ❑ Medium: Some cranes for material handling, line indexing, and some CNC equipment
- ❑ High: CNC equipment—using robotics instead of human workers for the bulk of the plant's production

b. Does the plant have a formal maintenance plan? (check one)

- ❑ Yes
- ❑ Yes and current
- ❑ No

5. Company's labor force:

a. Existing labor to meet current production—line workers/supervisors (check one).

- ❑ Less than 50
- ❑ 50 to 100
- ❑ 100 to 150
- ❑ 150 to 200
- ❑ More than 200

Worksheet: Assessment of Existing Factory-Built Plants (2 of 2)

b. Maximum "available" labor for maximum production—line workers/supervisors (check one).

- ❑ Less than 50
- ❑ 50 to 100
- ❑ 100 to 150
- ❑ 150 to 200
- ❑ More than 200

c. Indirect labor (Key Management Types)—(check all that apply):

- ❑ General Manager
- ❑ Marketing Manager
- ❑ CFO
- ❑ HR Director
- ❑ Accounts Payable and Receivable
- ❑ Purchasing Manager
- ❑ Operations Clerk
- ❑ Engineering Manager/QA
- ❑ Production/Plant Manager

6. Type of services that the company offers (e.g., design the house, build the house, deliver the house to site, set the house, inspections, & service calls) check all that apply

- ❑ Design
- ❑ Build – at the plant
- ❑ Deliver
- ❑ Site prepping – leveling, foundation, etc.
- ❑ House setting—install on site
- ❑ Inspections
- ❑ Service calls—during warranty period

7. Estimated time for building, transporting, setting, and finishing the desired house size.

- ❑ Design: _____
- ❑ Build – at the plant: _____
- ❑ Deliver: _____
- ❑ Site prepping – leveling and foundation: _____
- ❑ House setting – on site: _____
- ❑ Inspections: _____

8. Generally, what is the lead-time (months) necessary to start production of a new house design?

_____

9. Understanding that the company has current customers, how many houses can the company provide annually (available production capacity) as part of a major rebuilding effort?

_____

10. Is the company capable of expanding to meet a major housing order from a new customer?

❑ Yes ❑ No

If yes, how would the company expand capacity (i.e., expand existing facility, build new facility, or convert a vacant facility)?

_____
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Appendix B: **Sources for Product Prices/Notes**

Chapter 2 Tables

2-5a http://www.polyperformance.com/shop/Ready-Welder-II-10000APD-p-16594.html

2-6a http://www.loghomesupply.com/prazi-log-beam_382_p.htm

2-7a http://www.toolorbit.com/Jet/Jet-414600.html

2-9a http://www.carpetstretcher.net/home.php

2-9b http://www.acetoolonline.com/ShoppingCart.asp

2-10a Installed costs

2-12a http://www.industrialladder.com/productDetails.do?productID=2788

2-12b http://www.findkenworthtrucks.com/?gclid=CIuFhIKpp6ECFUI65QodnimoAg

2-17a http://www.generatorjoe.net/subcatmfgprod.asp?0=541&1=552&2=-1

2-17b http://www.durableaircompressors.com/IH1195023-Air-Compressor.html

2-17c http://www.stylefeeder.com/i/yc4f9bnb/Vaughan-Vauss10-36-In-Sledge-Hammer-10-Lb?sw=1

2-17d http://www.nextag.com/Stanley-London-Stanley-42-77162692/prices-html?nxtg=93c10a240519-EB574F8BADA78DC9

2-17e http://www.capcityequipment.com/gchalk.html

2-17f http://www.globalindustrial.com/g/material-handling/hand-trucks-dollies/hand-trucks-aluminum/global-aluminum-hand-trucks

2-17g http://www.builderdepot.com/browse.ihtml?pid=30868&step=5&prodstoreid=10021

Chapter 3 Tables

3-5a http://www.acetoolonline.com/Milwaukee-6577-20-7-1-4-Worm-Drive-Circular-Saw-w-p/mil-6577-20.htm

3-6a http://www.pmcwood.com/pmc_product.php?pmcID=JT-414600

3-8a http://www.carpetstretcher.net/home.php

3-8b http://www.acetoolonline.com/ShoppingCart.asp

3-9a Installed costs

3-11a http://www.industrialladder.com/productDetails.do?productID=2788

3-11b http://www.findkenworthtrucks.com/?gclid=CIuFhIKpp6ECFUI65QodnimoAg

3-12a http://www.generatorjoe.net/subcatmfgprod.asp?0=541&1=552&2=-1

[3-12b] http://www.durableaircompressors.com/IH1195023-Air-Compressor.html

[3-12c] http://www.stylefeeder.com/i/yc4f9bnb/Vaughan-Vauss10-36-In-Sledge-Hammer-10-Lb?sw=1

[2-13d] http://www.nextag.com/Stanley-London-Stanley-42-77162692/prices-html?nxtg=93c10a240519-EB574F8BADA78DC9

[2-13e] http://www.capcityequipment.com/gchalk.html

[2-13f] http://www.globalindustrial.com/g/material-handling/hand-trucks-dollies/hand-trucks-aluminum/global-aluminum-hand-trucks

[2-13g] http://www.builderdepot.com/browse.ihtml?pid=30868&step=5&prodstoreid=10021

Chapter 4 Tables

[4-5a] http://www.trussmachineryconnections.com/linear-saws.htm

[4-5b] Includes wall jig with stops

[4-6a] http://www.woodtrusssystems.com/index.php?src=directory&view=Listings&submenu=usedequipment&srctype=Listings_lister&pos=20,10,291

[4-7a] http://www.acetoolonline.com/Milwaukee-6577-20-7-1-4-Worm-Drive-Circular-Saw-w-p/mil-6577-20.htm

[4-8a] http://www.findkenworthtrucks.com/?gclid=CIuFhIKpp6ECFUI65QodnimoAg

[4-13a] http://www.generatorjoe.net/subcatmfgprod.asp?0=541&1=552&2=-1

[4-13b] http://www.durableaircompressors.com/IH1195023-Air-Compressor.html

[4-13c] http://www.stylefeeder.com/i/yc4f9bnb/Vaughan-Vauss10-36-In-Sledge-Hammer-10-Lb?sw=1

[4-13d] http://www.nextag.com/Stanley-London-Stanley-42-77162692/prices-html?nxtg=93c10a240519-EB574F8BADA78DC9

[4-13e] http://www.capcityequipment.com/gchalk.html

[4-13f] http://www.globalindustrial.com/g/material-handling/hand-trucks-dollies/hand-trucks-aluminum/global-aluminum-hand-trucks

[4-13g] http://www.builderdepot.com/browse.ihtml?pid=30868&step=5&prodstoreid=10021

Resources

Manufactured Housing

There are several resources that support manufactured housing, including HUD's Office of Manufactured Housing Programs, the IBTS, and the Manufactured Housing Institute (MHI).

http://www.hud.gov/offices/hsg/ramh/mhs/mhshome.cfm (HUD's Office of Manufactured Housing Programs)

http://www.ibts.org/index.shtml (IBTS website)

http://www.factorybuilthousing.com/Default.asp (MHI website)

Modular Housing

There are several resources that support modular housing including the NAHB Building Systems Council, the IBTS, and the IBC.

http://www.nahb.org/page.aspx/category/sectionID=809 (NAHB Building Systems Council—Modular Homes)

http://www.ibts.org/mod_home.shtml (IBTS Modular Home State Certification Labels)

http://www.interstateibc.org/about.htm (IBC Function and Modular Home State Certification Labels)

Panelized Housing

There are several resources that support panelized housing including the NAHB Building Systems Council and the IBTS.

http://www.nahb.org/page.aspx/category/sectionID=809 (NAHB Building Systems Council—Panelized Homes)

http://www.ibts.org/mod_home.shtml (IBTS support for factory-built systems)

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