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## Sullivan Sustainable Housing Unit

Riem Rostom  
*Indiana State University*

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# Sullivan Sustainable Housing Unit

ENGR 401 | SP 2021  
Heat Transfer

Dr. Riem Rostom  
College of Technology

This report represents original student work and recommendations prepared by students in the Indiana State University Sustainable City Program for the City of Sullivan. Text and images contained in this report may not be used without permission from Indiana State University. All information provided is not subject to publication.

# ACKNOWLEDGMENTS

The authors wish to acknowledge and thank the City of Sullivan for making this project possible. We would like to thank the staff and Mayor Lamb for their direction and vision that helped for the completion of this report. We would also like to thank the students in IAD251 fall semester for their work that we built upon.

**Mayor Clint Lamb**, *City of Sullivan*

## **ABOUT SC**

The Sustainable Cities (SC) Program is an experiential learning partnership focusing on sustainability and cities in Indiana. Disciplines across the institution are tasked with addressing sustainability issues in a specific community by integrating these into experiential projects for ISU students. These problems range from strategic planning recommendations to community needs assessment, and understanding the impacts of waste strategies to mapping trail systems, and many other issues.

This is a year-long partnership, in which students and faculty in courses collaborate with one specific community partner on these projects. Communities throughout Indiana have leaders who want to make real change. These leaders are passionate about moving their cities forward into the future, but are often limited by lack of resources, staff, and budget.

The SC Program utilizes the innovation and energy of students and faculty to provide ideas that will address these issues. This relationship reinforces and strengthens our Indiana communities.

Each ISU course and community partner will produce tangible and relevant outcomes for the community partner while providing ISU students with real world project completion. This report serves as this outcome.

## **SC PLANNING COMMITTEE**

Nancy Rogers, Ph.D., Vice President for University Engagement

Greg Bierly, Ph.D., Dean of the Honors College

Heather Dalton-Miklozek, Ph.D., Director of the Center for Community Engagement

Daniel Pigg, Director of the Business Engagement Center

Garrett Hurley, Interim Sustainability Coordinator

## ABOUT SULLIVAN, IN

Sullivan, IN is the county seat of Sullivan County and serves as a hub for the towns of Carlisle, Dugger, Farmersburg, Hymera, Merom, and Shelburn. Sullivan, IN was founded in 1853 and became the county seat. The total city limits is 1.88 square miles, but there are more residents living outside of this area that contribute to the community of Sullivan. Today, Sullivan has the largest estimated population as an incorporated town in Sullivan County.

Sullivan faces many similar social, environmental, and economic challenges to other rural Hoosier towns and others that are unique to the city itself. There are approximately 8,500 people available for the labor force in Sullivan County. Since 2009, the unemployment rate has steadily decreased in the county. There's approximately 2,500 people that live in Sullivan but work in other counties. Some of the major employers in Sullivan are Raybestos Powertrain LLC, Hoosier Energy Emergency, Peabody Energy Corp., Sullivan County Community Hospital, and Raybestos Products Co.

A common thought among Sullivan community members is that students that go to college graduate and don't return to Sullivan. The highest degree attainment of folks 25 and older in Sullivan County is a high school diploma. Trade programs and certifications are a community concern from folks.

Sullivan has a vast history and many points of interest in the community. The Sullivan County Public Library is one of 1,679 libraries designated as a Carnegie library. The Sullivan Civic Center was recently renovated to provide a central location for community member sin Sullivan. The Heart of Sullivan is a civic organization that hosts many large events throughout the year. One of the largest events hosted in Sullivan is the Sullivan Annual Rotary Corn Festival.

This community is full of potential and is being led through a strategic plan intended to bolster its standing for Hoosiers. The ISU Sustainable Cities program intends to help reach that potential.

# COURSE PARTICIPANTS

Nicholas Hutchinson

Austin Araiza

Alex Prather

Nathan Kiger

Jeffre Few

# TABLE OF CONTENTS

Introduction .....	8
Housing Unit .....	9
Heating/Cooling System .....	10
Solar Paneling .....	11
Appliances .....	12
Conclusion .....	13

## EXECUTIVE SUMMARY

Students in ENGR401 were tasked with providing recommendations for an energy efficient heating and cooling system for a housing design provided by IAD251. Students performed necessary calculations and compared information with sustainability factors. There are also further recommendations for building sustainable housing.



## INTRODUCTION

Sullivan, IN has empty lots, dilapidated lots, and other acquisitioned buildings within the city limits that have been identified as areas for new housing. The city identified a need for potential housing concepts and IAD251 students provided individual housing designs. The need for appropriate heating and cooling system recommendations was also identified as a need. The city has a partnership with Ohio Valley Gas Company and other partners that needed to be considered with housing.

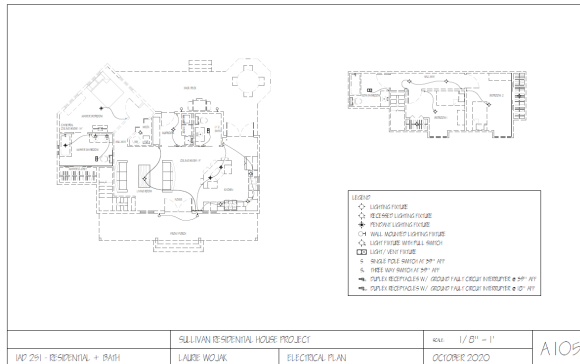
ENGR 401: Heat Transfer is a course for upper-division students in engineering. Students learn about heat transfer properties and associated calculations they will need to use. This course integrates housing and other building units into student learning for applicable scenarios. Students were tasked with providing recommendations on a heating and cooling system for a specific housing unit based off the information provided by the City of Sullivan and housing design by IAD251.

This required students to learn about the concepts and associated equations, and then calculate real units and numbers to provide recommendations.

The students enrolled in the course provided recommendations for a heating and cooling system based off their calculations and knowledge of resources in Sullivan. The students also provided recommendations for sustainable housing construction that will impact heating and cooling efficiency. These were presented in a final board and paper.

# HOUSING UNIT

IAD251 provided the City of Sullivan with 10 individual housing unit designs and the city selected one to provide to this class and receive recommendations. The housing units were designed with single family housing in mind and reflect the Sullivan neighborhoods.



Students were provided with the entire design that included floor plans, exterior elevations, interior elevations, potential materials and finishing's, and relevant files.

## HEATING / COOLING SYSTEM

Students identified the annual energy consumption based off the average monthly natural gas bill in Indiana and identified a heating/cooling system that had a 15 Season Energy Efficiency Ratio and was Energy Star Certified. Students also provided reasoning for the heating/cooling system based off desired efficiency.

Students calculated heat transfer based off the square footage of every room and identifying average temperatures for the Sullivan area. Winter heat transfer was calculated at -5251.54 BTU/h and summer heat transfer was calculated at 1969.33 BTU/h.

Based off these calculations, a 3 ton split system is needed to sufficiently heat and cool the home. A recommended model was the Carrier Comfort 15HP paired with the Comfort 95 gas furnace. This would be an outdoor heat pump that pulls outdoor air, warms it and sends it into the home where

the gas furnace will not have to consume as much energy as it would with the traditional outdoor condensing unit.

The costs are relatively low at \$3,000 for the whole system, but these are not the most efficient units. There are some units that are 15% more efficient but come with higher initial costs. If the greatest efficiency is desired for the home, then the Carrier Infinity series would be suitable at a price of \$6,000. There would be a higher return on investment (ROI) with the efficient unit. It depends on the type of home buyer you are intending to attract.

## SOLAR PANELING

Solar paneling is another way to increase energy efficiency of a home and increase sustainability within the neighborhood. Students wanted to provide solar paneling recommendations based off this housing unit design and placement.

Students paid attention to three important factors: (1) direction of the roof, (2) area on the roof for solar panel fitting, and (3) daily wattage usage in your home. The ideal placement for solar panels would be on the top left part of the west facing side of the housing unit. It could be optimal for setting up a set of four 64.57in by 39.06 in. solar panels. Each panel would produce 2.5 kWh in this area, which would be enough power to light the home. Any additional paneling would assist in powering appliances.

Total solar panel cost = \$1193.76

Savings per month = \$234

Time for ROI = 6 months

# APPLIANCES

Examining the appliances that would be used in this housing unit design reveal that there are different sustainable features that could improve energy efficiency. This housing unit requires 11 lights, 6 wall mounted lights, 3 vent lights, 3 hanging lights, 1 fridge, 1 water heater, 1 HVAC system, 1 washer/dryer unit, 2 bath units, and 3 toilets.

## Lights

A good ratio of 1:2 for wattage and output is ideal.

## Fridge

The compressor of the fridge is normally positioned on the bottom due to its heavy weight, and this produces most of the heat of the fridge. Ensuring a refrigeration unit purchased does not have the freezer located on the bottom next to the compressor is ideal.

## Water Heater

A tank-less water heater is ideal as the water is heated by electrical or gas burners and sent to where it is needed in the home. It is a more efficient appliance than tank water heaters that are likely to increase water bills, gas/electric bills, and increasing possibility of flooding.

## HVAC

A heat pump and air handler split system would be ideal for this housing unit as it is relatively low-cost and keeps the home well vented.

## Washer/Dryer Unit

Ensuring the use of an Energy Star washer and dryer unit will ensure efficiency and lower monthly water bills.

Savings per month were calculated (appendix A) for each appliance recommended:

- Monthly electric bill = \$150
- Electric water heater = \$44
- Energy efficient fridge = \$25
- Low wattage lights = \$15

**Total savings per month = \$234**

# CONCLUSION

Sullivan, IN identified housing as a priority moving into the coming years, and tasked the students with providing heating/cooling system recommendations and sustainable home recommendations. These students provided recommendations based off calculations for the Sullivan area and specific housing design unit.

**The following recommendations for this housing design unit:**

1. Carrier Comfort 15HP & Comfort 95 gas furnace
2. Four solar panels on west facing roof
3. Energy Star refrigeration unit without bottom drawer freezer
4. Heat pump and air handler HVAC system
5. Energy Star washer and dryer units

## Appendix A.

Heat Transfer Final Project document.

## Sullivan Sustainable House

Nicholas Hutchinson, Austin Araiza, Alex Prather, Nathan Kiger, Jeffre Few

Course: ENGR 401 Heat Transfer

Instructor: Dr. Rostom

May 4<sup>th</sup>, 2021



## Summary

The Sustainable Cities group at Indiana State asked our Heat Transfer course to recommend an energy efficient heating and cooling system for a house in Sullivan, Indiana. We were provided with the drawings of the proposed house to perform the necessary calculations to meet the needs of the customer. The system recommendations below are based on the given constraints of natural gas power, relatively low initial cost while still having low energy consumption and low monthly utility costs.

## Annual Energy Consumption

The annual energy consumption was found based on the average monthly natural gas bill for Indiana. The bill is generally 30% less expensive than electricity being \$103.17. Taking this value multiplied by 12, gives the average annual bill of \$1238.04. The system recommended below is rated at 15 Season Energy Efficiency Ratio for heating and cooling, 13 Energy Efficiency Ratio of cooling and 8.5 Heating Seasonal Performance Factor. The system is also Energy Star certified.

## Calculations

The first calculations were figuring out the square footage of every room in the house and summing them up to get a total square footage of the house which was 1,462. Using the equation to convert square footage to BTU/hr to find the load, we took 1,462 multiplied by 20 to come up with 29,240 BTU/hr for the cooling load before appliances and people were taken into consideration. Adding four people and appliances heat expenditures resulted in a total cooling load of 33,000 BTU/hr. Dividing that value by 12,000 BTU/ton, results in 2.75 tons. Which makes the 3 ton recommendation below suitable for this application. The values for the heat transfer through the walls and roof were also calculated. The U-Values were determined in order to calculate the total heat transfer. In the winter, the total heat transfer was calculated at heat transfer to be -5251.54 BTU/h. In the summer, the total heat transfer calculated to be 1969.33 BTU/h.

## Recommendations

We would recommend a gas 3 ton split system to sufficiently heat and cool the home. The model researched was the Carrier Comfort 15HP paired with the Comfort 95 gas furnace. This would be an outdoor heat pump that pulls outdoor air, warms it and sends it into the home where the gas furnace will not have to consume as much energy as it would with a traditional outdoor condensing unit. These both have low initial costs at around \$3,000 for the whole system (labor not included). Full transparency, these units are not the upmost tier for efficiency but with efficiency comes much higher entry costs and these units are 15% more efficient than their 14 SEER counterparts. If the greatest efficiency is desired for this home, then the Carrier Infinity series would be suitable. However, this comes with a price tag of nearly \$6,000.

## Results

Based on our calculations, a 3-ton split system would be a cost effective and efficient choice for the Sullivan complex. After calculating annual heat consumption and finding average monthly natural gas bills we were able to find the heat load in the house. With a projected heat load at 2.75 tons, the 3-ton split system will be a good choice for the unit.

## Citation

Pete, Joseph S. "Indiana Has 29th Highest Utility Costs in the Country, Study Finds." *Nwitimes.com*, 24 Dec. 2018, [www.nwitimes.com/business/local/indiana-has-29th-highest-utility-costs-in-the-country-study-finds/article\\_2fd2f785-a01b-5c00-a05c-863d09c36eb2.html](http://www.nwitimes.com/business/local/indiana-has-29th-highest-utility-costs-in-the-country-study-finds/article_2fd2f785-a01b-5c00-a05c-863d09c36eb2.html).

Data.org. (n.d.). Retrieved May 04, 2021, from <https://en.climate-data.org/north-america/united-states-of-america/indiana/sullivan-134514/>

**Heat Transfer Final Project**

**Professor Riem Rostom**

**5/1/2021**

**Jeffre Few**

# Solar Panels

Personally used solar panels have been popping up around the world for the last decade where people are beginning to drastically cut down their electric bill. Though some questions still stand such as: what is a recommended number of solar panels for my house, does my house have to be facing the correct direction, and how long until they pay for themselves.

Solar panels normally come in rectangle sections ranging from 60 to 100 square feet, and with a larger surface area comes more kWh (Kilo Watts an Hour/Day) which is the basic measurement for most appliances.

Now for this home taking the top left section of the roofing on the west view facing side it could be optimal for setting up a set of four 64.57 by 39.06 inch solar panels with each producing 2.5 kWh of energy per day. This should be plenty of power in order to keep this home lit.

Now this number comes from taking the wattage of the solar panel and multiplying it by the average rate of sunlight per day which is 8 hours and multiplying it by the wattage which for this case is  $8 * 300 * 4 = 10 \text{ kWh}$ . Once we find our daily wattage usage it can be determined which appliances can run through this power source. This will also allow to be seen if a smaller or larger solar panel setup will be needed.

# Appliances

This home has

- 11 Lights
- 6 Wall Mounted Lights
- 3 Vent Lights
- 3 Hanging Lights
- 1 Fridge
- 1 Water Heater
- 1 HVAC System
- 1 Washer/Dryer
- 2 Bath
- 3 Toilets

**Lights-** With each of these appliances there are individual properties you may be looking for. Lights have the description of having a low wattage and higher output. Due to its design of the light it can produce a brighter and more natural look with a fraction of the power. A good ratio to look for in a light would be 1:2. An example of this would be if the product said it needed 30 watts minimum and while 60 watts of equivalent light.

**Fridge-** when it comes to the refrigerator there are a couple design components to keep in mind. One main one being that while the slide out freezer on the bottom may seem nice, it actually increases its overall energy usage. The Compressor of the fridge is normally positioned on the bottom due to its heavy weight. The compressor also produces most of the heat from the fridge to where if the freezer is located in the same area it would require more work in order to keep it at a safe temperature.

**Water Heater-** There are two main types of water heaters to choose from, with and without a tank. A tank water heater has been the bases in homes for a while now where it will fill up with water, heat it, and use that as the warm water through the house. Though with these kinds of water heaters there are a multitude of problems that go along with it such as, high water bills, electric/gas bills (depending on how the water is heated), not always having hot water at the ready, and when its shelf life is over there is a possibility of flooding. With tank less water heaters it gets warm water to you on demand. The water is either super-heated by electrical or gas burners and sent wherever you need it in your home. This is a highly recommended option due to the money you save, having a more reliable appliance, and longer usage life.

**HVAC-** There are a multitude of different kinds of HVAC systems but the one most notably useful for this home would be a heat pump and air handler split system. It is a relatively cheaper setup while also keeping the home well vented and at a comfortable temperature. The two down points of this setup is it may allow allergies to move through the home and struggles when it hits subzero temperatures. Though with these houses being set up in south Indiana there would only be a few days out of the year that would be uncomfortable while keeping the home economical.

**Washer/Dryer-** With washers and dryers you are normally looking for that Energy Star logo which certifies it as being energy efficient. Most dryers need to be vented in order to expel the excess heat to the outside. Also most washer and dryers will tell you their amplitude and voltage output which would allow you to acquire the wattage by using the formula ( $\text{Amp} * \text{Volt} = \text{Watt}$ ). With an energy star washer you can also decrease the amount of money spent on a water bill each month.

**Bathroom Items-** Appliances such as toilets, sinks, and shower heads, see most of the water usage in the house meaning that making sure these appliances are economically efficient is key. The average flow rate of a shower head is 2.5 gallons per minute. Getting anything under that would be economically beneficial, saving you upwards of 50 dollars a month. While another aspect of water usage is at the toilet with an average flush amount of 1.6 gallons. Just as same as the shower head, if you can get a toilet ranging more in the 1.1 to 1.3 range it could save up to \$110 dollars a year.

# Cost and Savings

So now comes the question of how much will this all cost and what are you saving. Assuming we are going off of customer retail price this would be the total for all of the appliances.

Toilet-----  $100 * 3 = 300$

Shower Head -----  $100 * 2 = 200$

Dryer ----- 900

Washer ----- 800

Lights -----  $72 * 24 = 1728$

Refrigerator ----- 668

Water Heater ----- 505

Solar Panel Set ----- 1200

**Total ----- \$6301**

## Savings per Year

Washer/Dryer ----- 50

Toilets -----  $110 * 3 = 330$

Shower -----  $50 * 2 = 100$

Lights ----- 100

Refrigerator ----- 75

Water Heater ----- 80

Monthly Electric Bill  $150 * 12 = 1800$

**Total = \$2535**

Time till appliances pay for themselves

**$6301 / 2535 = 2.48$  years.**

## Appliances Used

4.5 cu. ft. Ultra Large Capacity White Front Load Washing Machine with Coldwash Technology

<https://www.homedepot.com/p/LG-Electronics-4-5-cu-ft-Ultra-Large-Capacity-White-Front-Load-Washing-Machine-with-Coldwash-Technology-WM3400CW/312399923>

2-piece 1.1 GPF/1.6 GPF High Efficiency Dual Flush Complete Elongated Toilet in White, Seat Included

<https://www.homedepot.com/p/Glacier-Bay-2-piece-1-1-GPF-1-6-GPF-High-Efficiency-Dual-Flush-Complete-Elongated-Toilet-in-White-Seat-Included-N2316/100676582>

Attract with Magnetix 6-spray 6.75 in. Dual Shower Head and Adjustable Handheld in Spot Resist Brushed Nickel

<https://www.homedepot.com/p/MOEN-Attract-with-Magnetix-6-spray-6-75-in-Dual-Shower-Head-and-Adjustable-Handheld-in-Spot-Resist-Brushed-Nickel-26008SRN/305475615>

7.3 cu. ft. Ultra Large White Smart Electric Vented Dryer with EasyLoad Door & Sensor Dry, ENERGY STAR

<https://www.homedepot.com/p/LG-Electronics-7-3-cu-ft-Ultra-Large-White-Smart-Electric-Vented-Dryer-with-EasyLoad-Door-Sensor-Dry-ENERGY-STAR-DLE7300WE/308716328>

Brushed Nickel LED Round Flush Mount

<https://www.homedepot.com/p/Hampton-Bay-Brushed-Nickel-LED-Round-Flush-Mount-DC016LEDB/204490455>

17.5 cu. ft. Top Freezer Refrigerator in White, ENERGY STAR

<https://www.homedepot.com/p/GE-17-5-cu-ft-Top-Freezer-Refrigerator-in-White-ENERGY-STAR-GTE18DTNRWW/311102066>

Performance 27 kw Self-Modulating 5.27 GPM Tankless Electric Water Heater

<https://www.homedepot.com/p/Rheem-Performance-27-kw-Self-Modulating-5-27-GPM-Tankless-Electric-Water-Heater-RETEX-27/300800755>

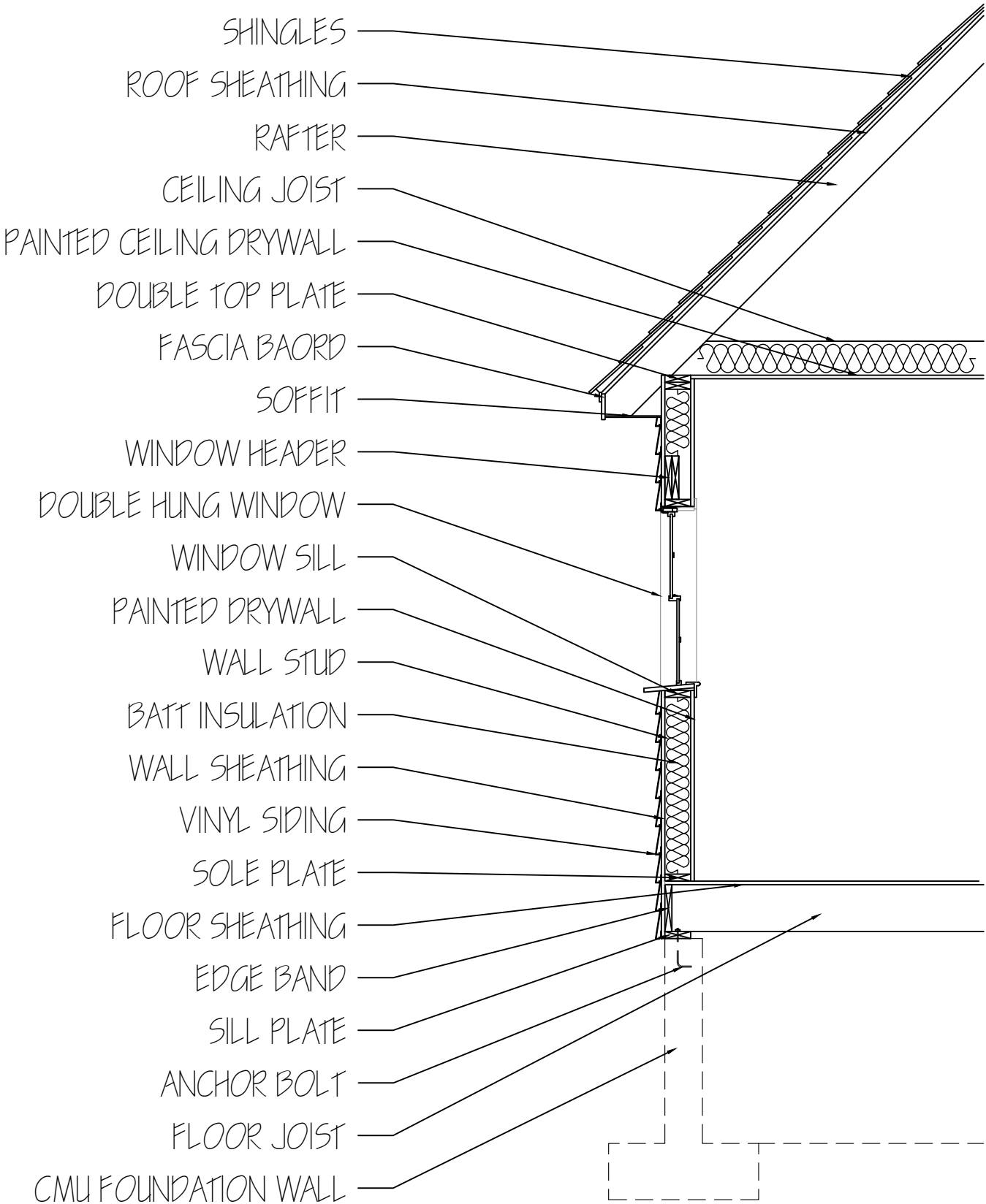
300-Watt Monocrystalline Solar Panel (4-Pack)

<https://www.homedepot.com/p/Grape-Solar-300-Watt-Monocrystalline-Solar-Panel-4-Pack-GS-M60-300-USx4/302023154#overlay>



## Appendix B.

IAD251 Housing Design unit.



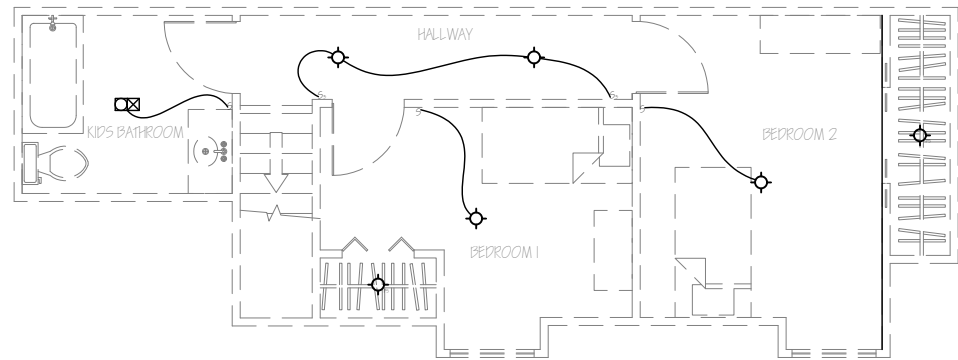
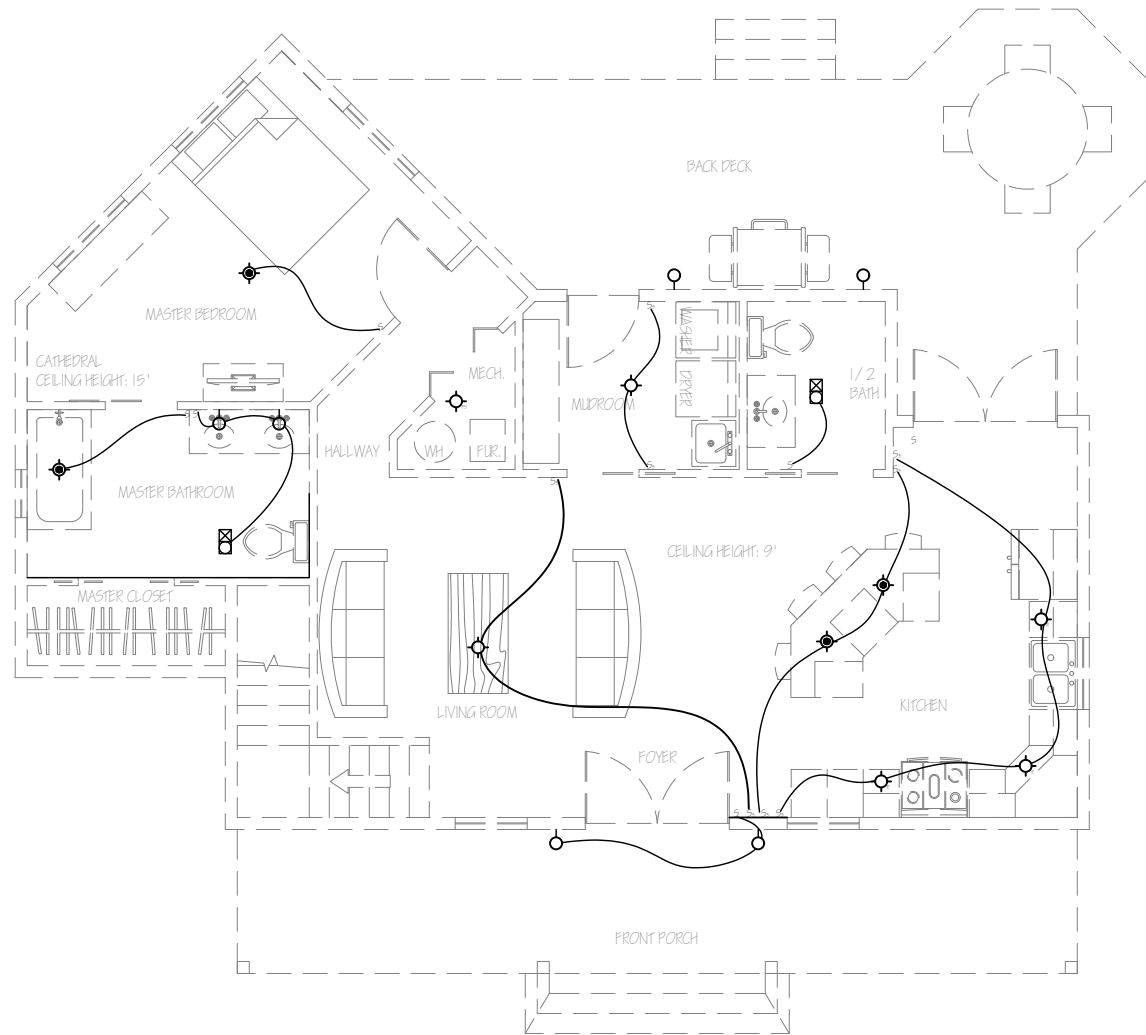
SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/4" = 1'	A105
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	OCTOBER 2020	

PRODUCED BY AN AUTODESK STUDENT VERSION

PRODUCED BY AN AUTODESK STUDENT VERSION



	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/4" = 1'	A107
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	EAST EXTERIOR ELEVATION	OCTOBER 2020	



LEGEND

LIGHTING FIXTURE

RECESSED LIGHTING FIXTURE

PENDANT LIGHTING FIXTURE

WALL MOUNTED LIGHTING FIXTURE

LIGHT FIXTURE WITH PULL SWITCH

LIGHT / VENT FIXTURE

S SINGLE POLE SWITCH AT 39" AFF

S<sub>3</sub> THREE WAY SWITCH AT 39" AFF

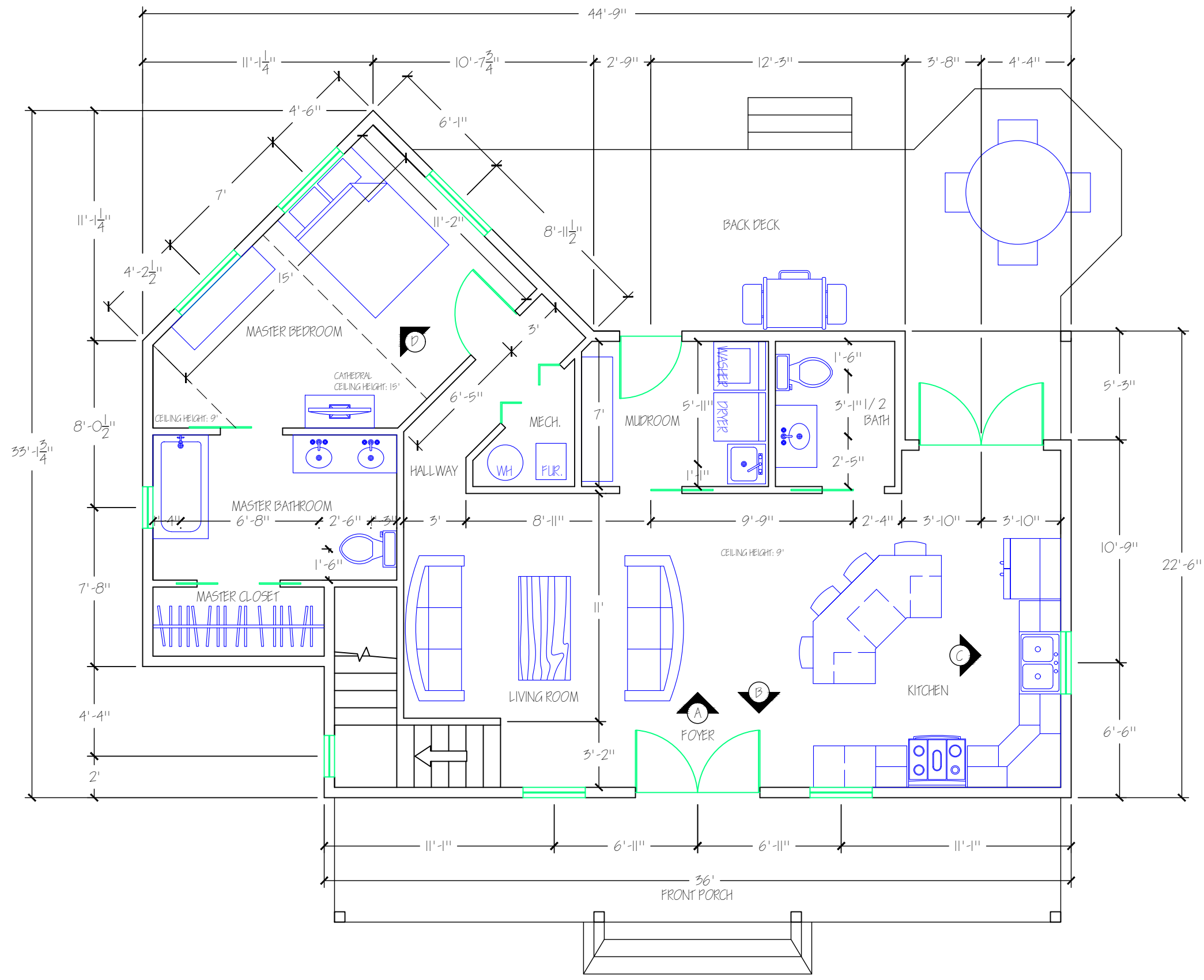
⌚<sub>2</sub> DUPLEX RECEPTACLES W/ GROUND FAULT CIRCUIT INTERRUPTER @ 39" AFF

⌚<sub>1</sub> DUPLEX RECEPTACLES W/ GROUND FAULT CIRCUIT INTERRUPTER @ 18" AFF

	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/8" = 1'	A105
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	ELECTRICAL PLAN	OCTOBER 2020	

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SULLIVAN RESIDENTIAL HOUSE PROJECT

SCALE: 3/16" = 1'

IAD 251 - RESIDENTIAL + BATH

LAURIE WOJAK

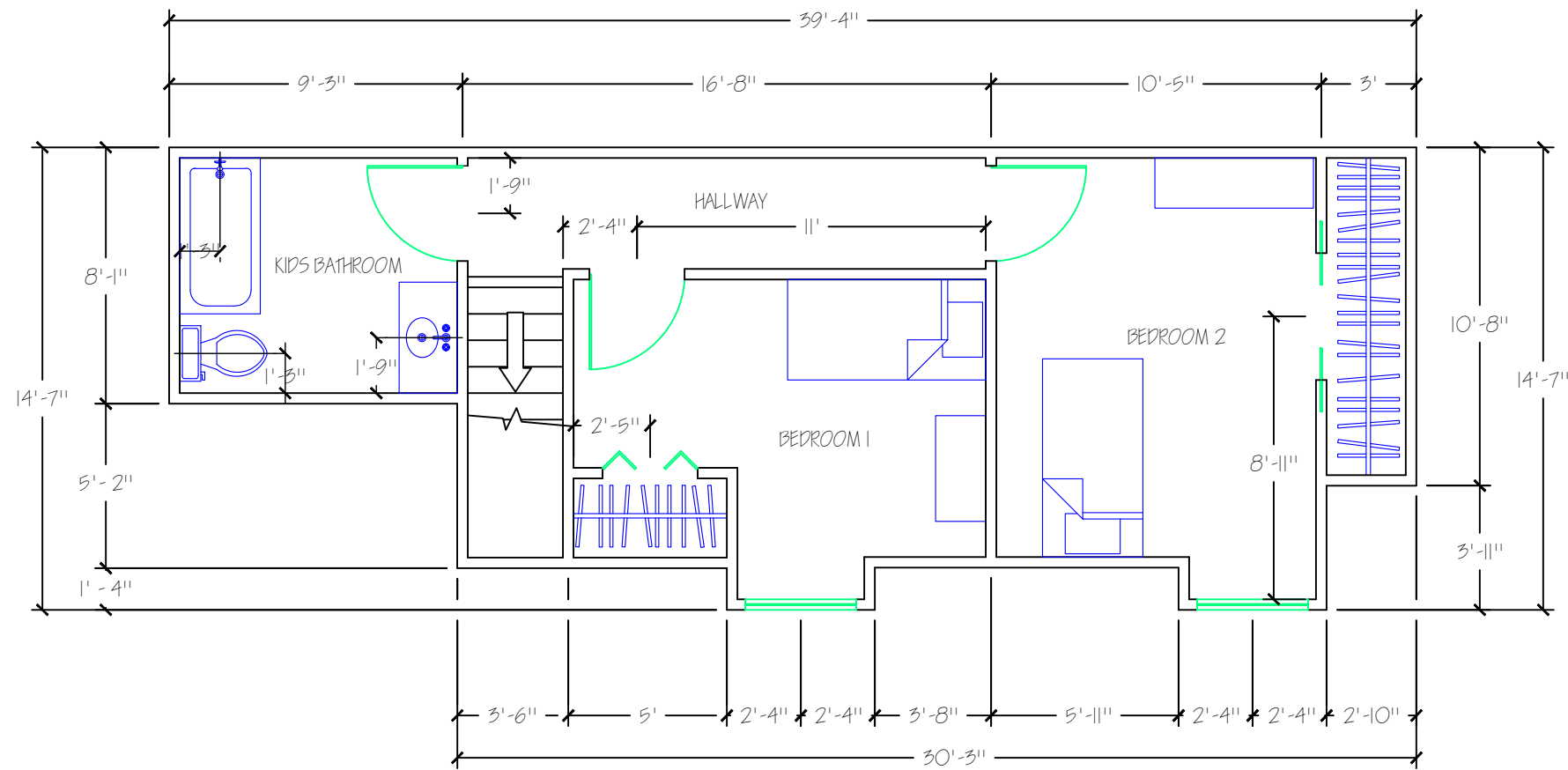
LEVEL 1 FLOOR PLAN

OCTOBER 2020

A101

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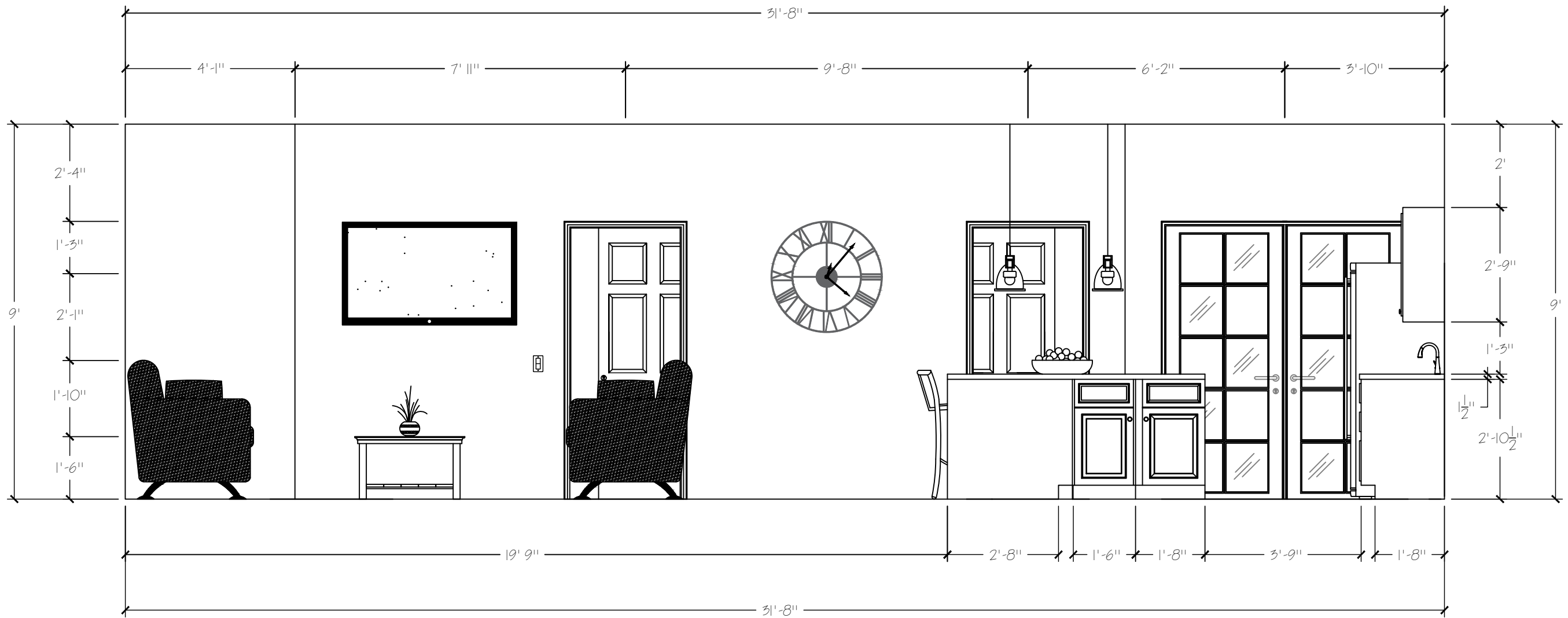
PRODUCED BY AN AUTODESK STUDENT VERSION



SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 3/16" = 1'	A102
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	LEVEL 2 FLOOR PLAN	
		OCTOBER 2020	

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	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 3/8" = 1'	A 110
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	INTERIOR ELEVATION A: LIVING SPACE	OCTOBER 2020	

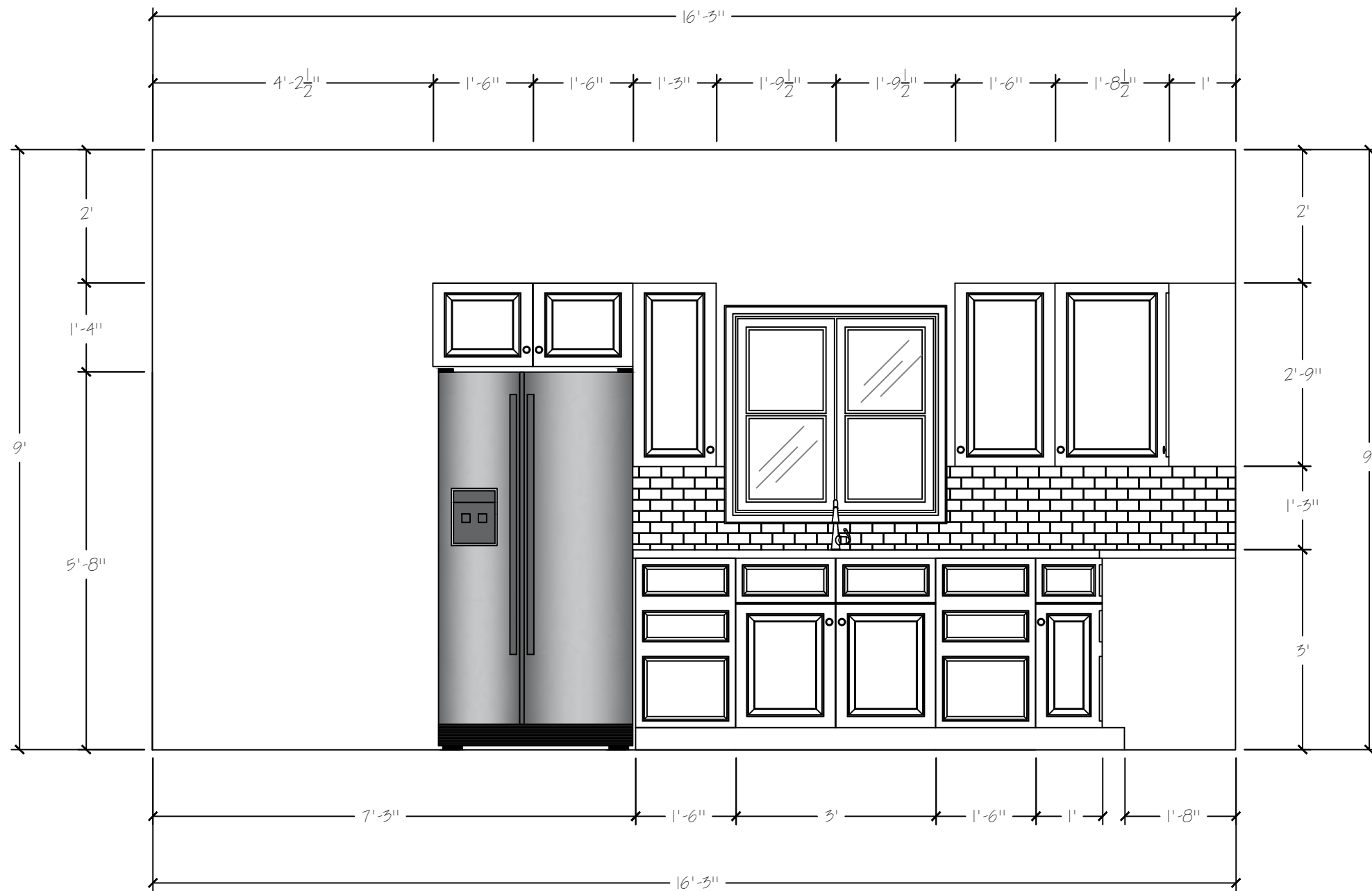
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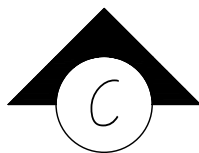


SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 3/8" = 1'	A III
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	OCTOBER 2020	

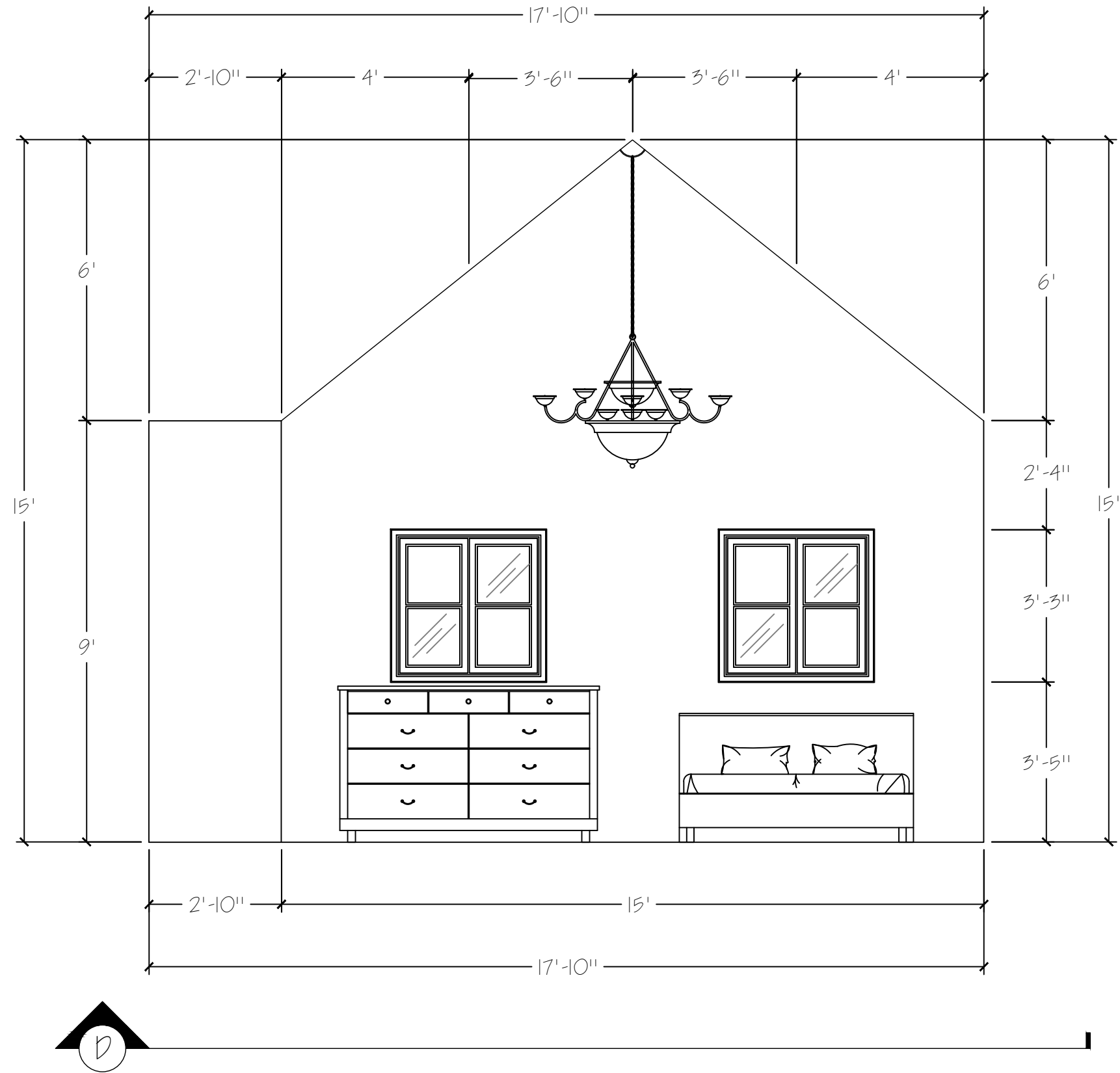




STAINLESS STEEL REFRIGERATOR  
WHITE SUBWAY TILE BACKSPLASH  
OAK CABINETS PAINTED WHITE  
GRANITE COUNTERTOP  
STAINLESS STEEL SINK



	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/2" = 1'	A 112
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	INTERIOR ELEVATION C: KITCHEN	OCTOBER 2020	



### NOTES

15' CATHEDRAL CEILING  
PAINTED DRYWALL  
OAK CABINETS PAINTED WHITE  
QUEEN SIZE BED  
6 DRAWER WHITE DRESSER

SULLIVAN RESIDENTIAL HOUSE PROJECT

SCALE: 3/8" = 1'

IAD 251 - RESIDENTIAL + BATH

LAURIE WOJAK

INTERIOR ELEVATION D: MASTER BED

OCTOBER 2020

A113

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PRODUCED BY AN AUTODESK STUDENT VERSION

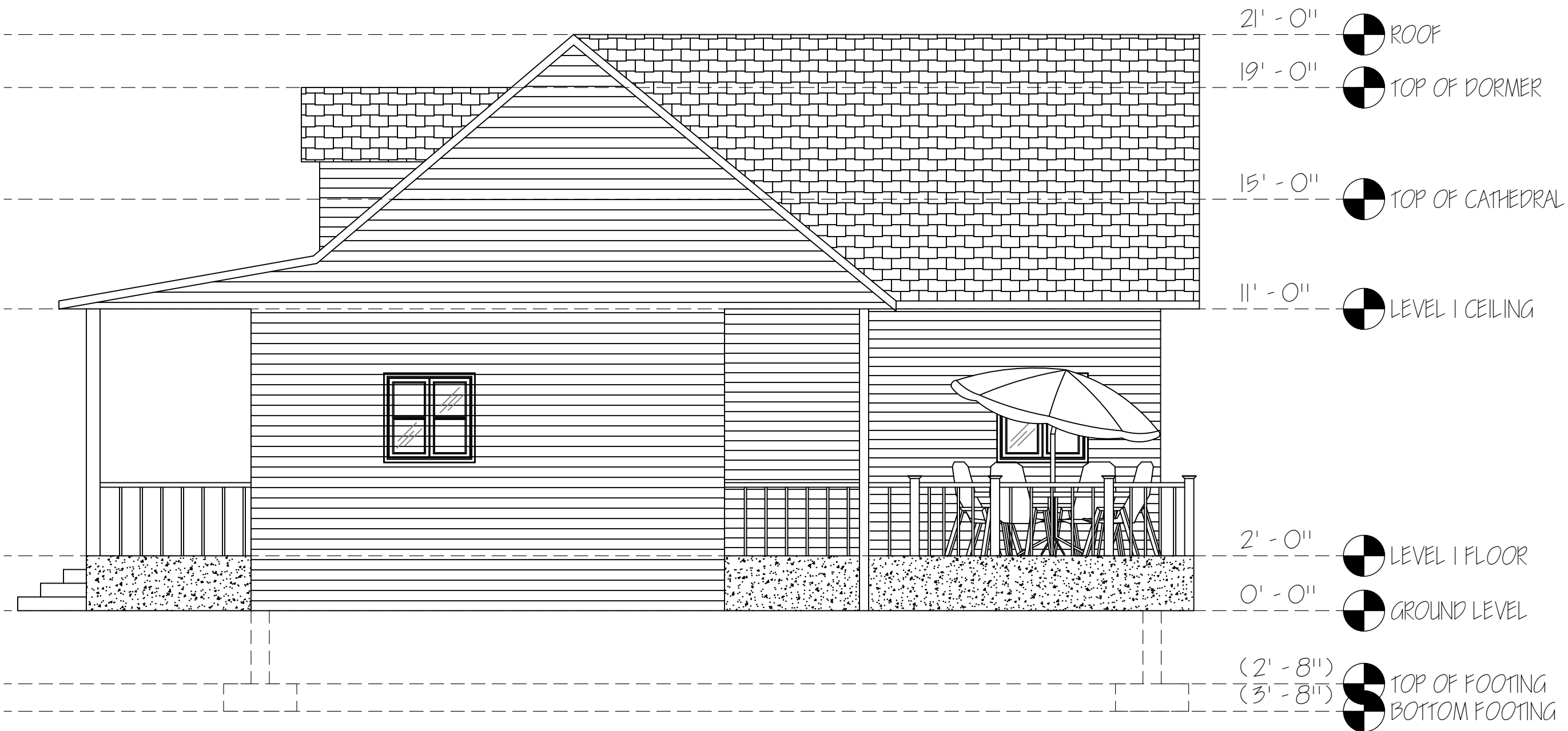


NORTH EXTERIOR ELEVATION

	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/4" = 1'	A109
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	NORTH EXTERIOR ELEVATION	OCTOBER 2020	

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	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/4" = 1'	A108
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	SOUTH EXTERIOR ELEVATION	OCTOBER 2020	

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PRODUCED BY AN AUTODESK STUDENT VERSION



WEST EXTERIOR ELEVATION

	SULLIVAN RESIDENTIAL HOUSE PROJECT		SCALE: 1/4" = 1'	A106
IAD 251 - RESIDENTIAL + BATH	LAURIE WOJAK	WEST EXTERIOR ELEVATION	OCTOBER 2020	