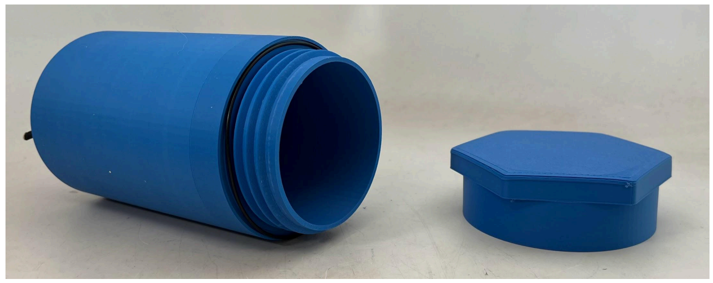
ENTS NODE ENCLOSURE INSTRUCTION MANUAL

To deploy the ENTS node there are several options for its enclosure. Outlined in the instruction manual below is a guide on how to select, manufacture and assemble your own ENTS enclosure.

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1. Picking your Enclosure Type

The first step is to decide which enclosure to assemble. There are 2 enclosure options: a 3D printed option and a PVC option. The choice between different enclosure types ultimately comes down to the user's preference but depends on several factors, including cost, working time, idle time, tools readily available and individual concerns. It is important to consider the amount of enclosures needed, as cost and time scale differently. This section will guide you through the key consideration for choosing between each enclosure, helping you make an informed decision based on your needs and preferences.

Table 1: Comparing Properties of different enclosures.

	3D Printed	**PVC**
Cost	$28	$35
Build Time	15 minutes	30 minutes
Idle Time	20 hours	2.5 hours
Tool/Assembly Requirements	3D Printer, PLA, Sealant, O-Ring Lubricant	PVC Cement, Power Drill, Saw, Teflon Tape
Concerns	Reproducibility, Longevity	Size, Scalability

- **Cost** : Total material cost of enclosure, excluding materials that can be used on multiple enclosures
- **Build Time:** Active/Hands on time required per enclosure
- **Idle Time :** Waiting period required for items to print/cure
- **Tool Requirements :** Ensure you have access to the necessary tools and equipment

Below is the Manufacturing & Assembly guide for the 3D Printed and PVC enclosures.

2. Manufacturing & Assembly

2.1. PVC Option

2.1.1. Overall Design

The PVC enclosure is designed using standard 4” Schedule 40 (SCH 40) PVC pipes and fittings. Figure 1 below illustrates the components involved in the PVC enclosure.

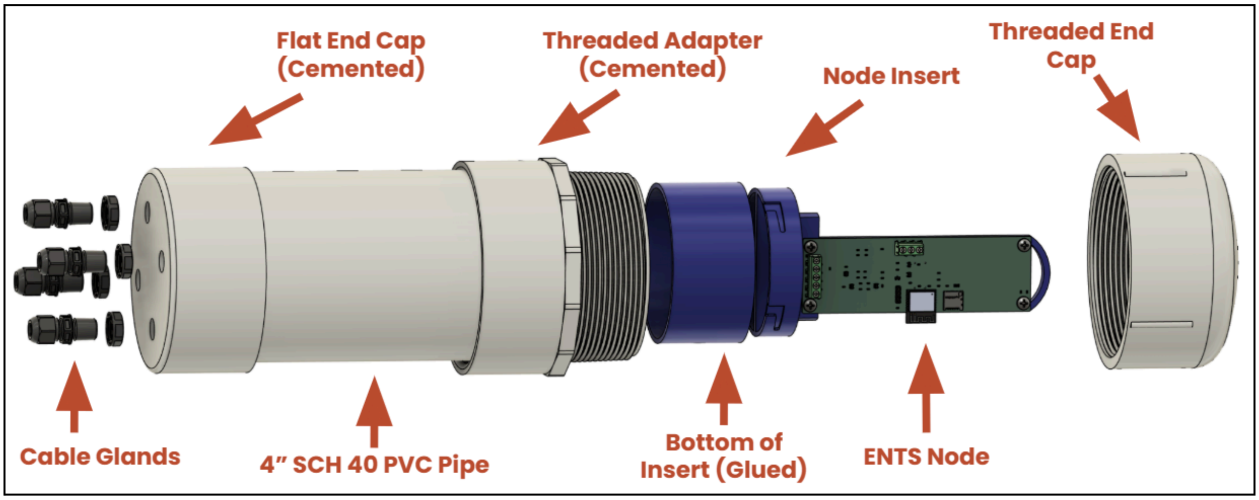


Figure 1: PVC Enclosure Component Diagram

2.1.2. Acquiring Materials

All components used for manufacturing a PVC enclosure may be procured from external suppliers. The required materials include those listed in the table below as well as cable glands, outlined in Section 2.1.3.

Table 2: PVC Design Materials

Material	Procurement Link	Upfront Cost	Uses	Cost / Enclosure
PVC Pipe	Home Depot (2’)	$17.86	3	$5.93
	PipeSupply(10')*	$79	15	$5.26
Male Adapter	Home Depot	$10.84	1	$6.99
	PipeSupply*	$6.99		
Threaded End Cap	Home Depot	$14.96	1	$7.99
	Grainger	$9.18		

	PipeSupply*	$7.99		
Female Socket End Cap	Grainger	$25.86	1	$10
	Amazon	$10		
PVC Primer and Cement (multi-use)	Home Depot	$9.06	~3.5	$2.6
Teflon Tape (¾ in., multi-use)	Amazon	$7.59	~17	$0.46
	Total Cost :	$59.49	$33.30	

* PVC Pipe Supply has a minimum order of $25

2.1.3. Cable Gland Setup

- **Selection :** Choose cable glands based on your specific cable requirements. Refer to Section 3.2 for more information on selecting and procuring cable glands.
- **Drilling Holes :** Depending on your individual use case there are possible cable gland configurations necessary. Drill holes in the flat female socket end cap to accommodate the cable glands, ensuring the correct diameter for your chosen cable gland, as detailed in Section 3.2.
- **Sealing (optional) :** For additional protection, seal the interface between the cable gland and the enclosure with aquarium silicone sealant.

2.1.4. Cutting to Size

- **Cutting the PVC Pipe :** Use a power-driven saw, preferable option, or a hand saw to cut the PVC pipe to a length of 8 inches. Remove any protruding plastic from the cut area, with sandpaper, to ensure smooth cementing.
- **Safety Precautions :** Always follow safety guidelines when operating power tools.

2.1.5. Assembly

Once all materials are procured and any modifications of materials conducted (drilling holes for cable glands), assembly may begin;

- **Preparing Components :** Apply PVC primer to the inside of the female socket end cap and the end of the PVC pipe. Wait about 10 seconds before applying PVC cement to both coated areas and joining them immediately.
- **Secure the Male Adapter** : Apply PVC primer and cement to the inside of the PVC male adapter and the other end of the cut PVC pipe, then join them immediately.

- **Allow Cement to Cure :** Let the PVC cement cure for 30 minutes in a well-ventilated area to avoid inhaling fumes.
- **Applying Teflon Tape :** Wrap ¾ inch Teflon tape around the threads of the PVC male adapter in a clockwise direction, overlapping the tape to ensure a secure seal. Apply 4 to 5 layers of tape. A fresh application is required each time the lid is opened in order to guarantee a waterproof enclosure.

2.1.6. Node Insert (Optional)

A Node Insert can optionally be 3D printed in order to keep the node in place during deployment. See Section 3.2 for more information.

2.1.7. Deployment

- **Tighten Lid :** Once teflon tape is applied, tighten the lid as much as possible by hand.
- **Test Enclosure :** Although iterations of this enclosure have lasted for a week submerged under water, and PVC is designed for related applications, installation conditions always vary. It is recommended to test your fully assembled enclosure with paper towels, for a week, before using it with your ENTS node.

After all of these steps have been completed your enclosure is ready for outdoor deployment!

2.2. 3D Printed Option

2.2.1. Overall Design

The 3D printed design used standard PLA filament with optimized printing setting, sealant and an o-ring to ensure a durable enclosure. A provided stl file includes an o-ring groove and holes for cable glands, although the corresponding items must be procured, details in section 2.2.2 & 2.2.3. Figure 2 below illustrates the components involved in the 3D printed enclosure.

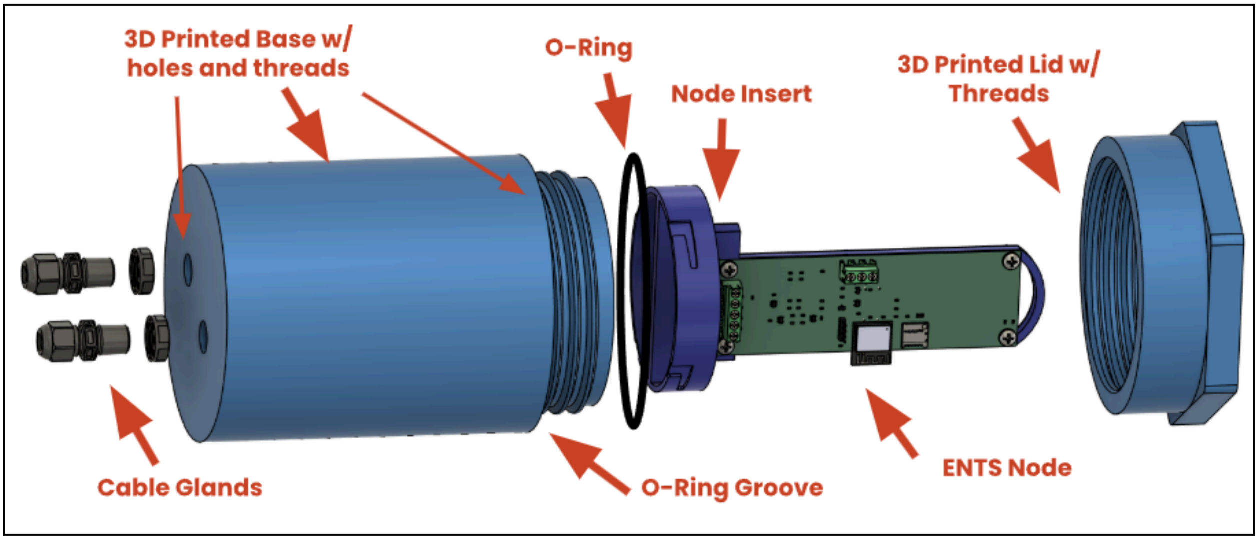


Figure 2: 3D Print Enclosure Component Diagram

2.2.2. O-Ring Configuration

- **Size :** The enclosure is designed for a 2mm width, 115 mm ID Buna-N O-Ring. However, the O-Ring size can be modified using the 3D print parameters specified in Section 2.23. The gland is designed using Parker's handbook.
- **Procurement** : O-Rings were procured from Mc-Master Carr, which also carries other sizes if needed.

2.2.3. Cable Gland Holes Configuration

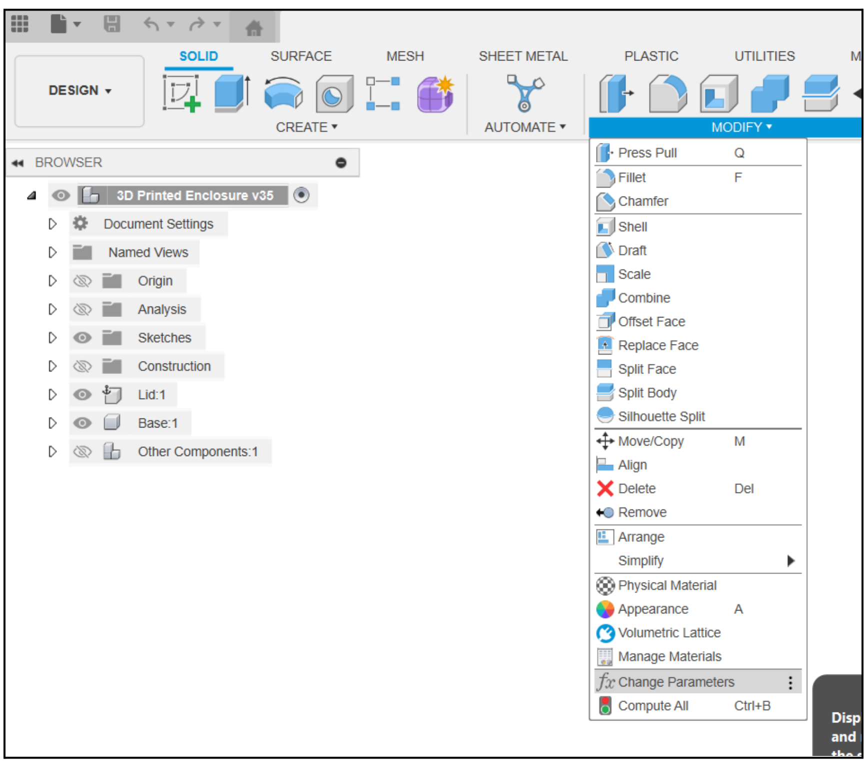
- **Cable Gland Selection :** Choose cable glands based on your specific cable requirements. Refer to Table 3 in Section 3.1 for cable gland options and their specifications.
- **Hole Diameter :** Ensure the 3D print holes match the clearance hole diameter for your chosen cable glands. If not specified, add 0.6 mm to the outer diameter of the threads as a general guideline.

2.2.4. Preparing 3D Print

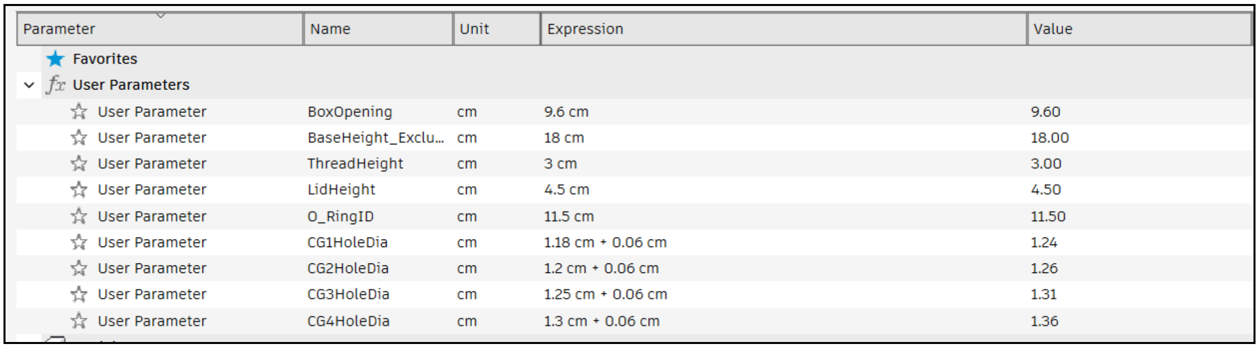
The Enclosure was designed using Autodesk Fusion 360 CAD software and its Autodesk Fusion File (3D Printed Enclosure.f3z) download link has also been provided on the GitHub for easy customization, in addition to the default configuration STL files (3D Print Enclosure Base/Lid.stl). Note that the STL files have dimensions for specific component sizes. For example, the cable gland holes are dimensioned for the TE Connectivity M12 1.5 cable glands featured in Table 4 in Section 3.1. Most enclosure dimensions will not need to be altered often, aside from the Cable Gland Hole Diameters which may need to be altered depending on the cable glands purchased/used, see Table 3 below for more details. The CAD comes with 4 default cable gland holes and you can remove a cable gland hole by setting its diameter to 0. The enclosure is composed of two components: the lid and the base.

User parameters were used to define key dimensions of any potential enclosure design. The parameter window is accessed by:

1. Clicking on the “Modify” dropdown in Fusion 360
2. Selecting “Change Parameters”. This prompts a pop-up window where you can alter your enclosure variables



3. These parameters are in centimeters and include:



Parameter	Name	Unit	Expression	Value
Favorites				
User Parameters				
User Parameter	BoxOpening	cm	9.6 cm	9.60
User Parameter	BaseHeight_Exclu...	cm	18 cm	18.00
User Parameter	ThreadHeight	cm	3 cm	3.00
User Parameter	LidHeight	cm	4.5 cm	4.50
User Parameter	O_RingID	cm	11.5 cm	11.50
User Parameter	CG1HoleDia	cm	1.18 cm + 0.06 cm	1.24
User Parameter	CG2HoleDia	cm	1.2 cm + 0.06 cm	1.26
User Parameter	CG3HoleDia	cm	1.25 cm + 0.06 cm	1.31
User Parameter	CG4HoleDia	cm	1.3 cm + 0.06 cm	1.36

Figure 3: Parameter Dropdown

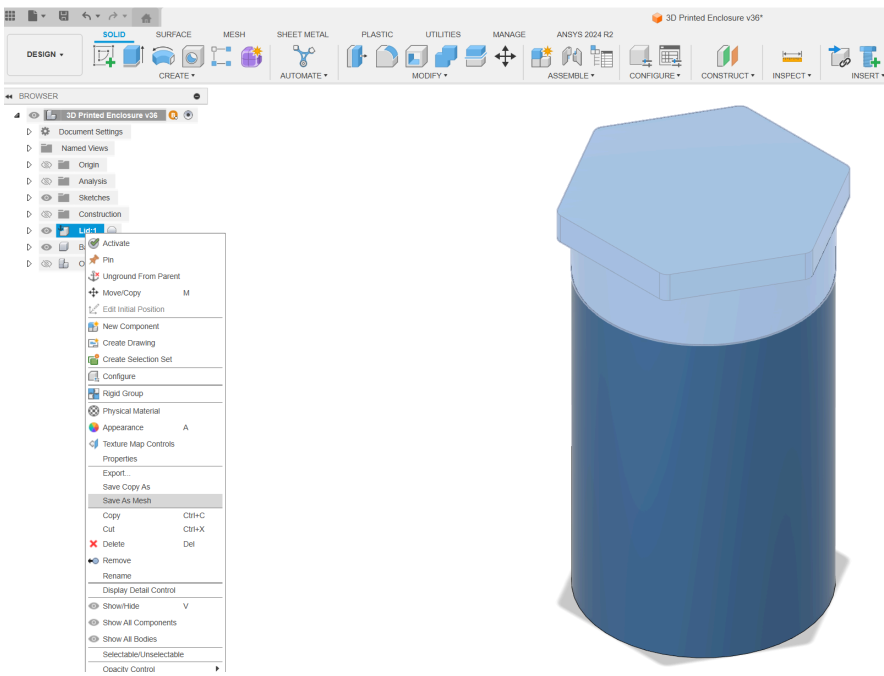
Table 3: Enclosure Parameter Details

Parameter	**Description**
BoxOpening	Diameter of the circular opening of the enclosure's base
BaseHeight_ExcludingThreads	The height of the base excluding the threads, from the bottom of the base to the start of the threads
ThreadHeight	Height of the base's threads and the lid's thread cavity
LidHeight	Total height of lid
O_RingID	Inner diameter of O-Ring
CG1HoleDia	Clearance Hole Diameter of Cable Gland 1 (set to 0 to remove)
CG2HoleDia	Clearance Hole Diameter of Cable Gland 2 (set to 0 to remove)
CG3HoleDia	Clearance Hole Diameter of Cable Gland 3 (set to 0 to remove)
CG4HoleDia	Clearance Hole Diameter of Cable Gland 4 (set to 0 to remove)

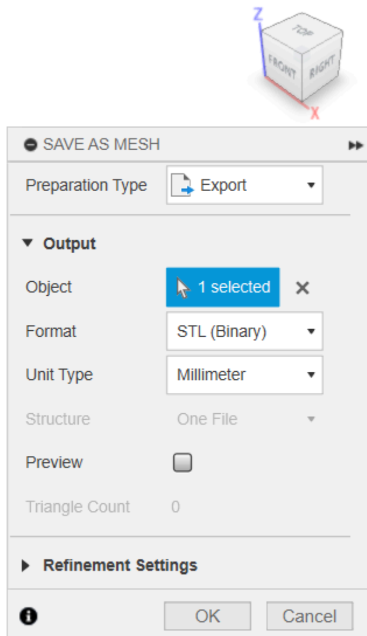
* Note: If you need more than 4 Cable gland holes you can alter the CAD manually to add more holes on the bottom surface. For the cable gland hole diameters, if a recommended clearance hole diameter is not specified from the manufacturer, our recommendation is to measure the cable gland's thread diameter and add 0.06 cm to obtain the clearance hole diameter.

2.2.5. Printing Enclosure

- **STL File :** If you changed any parameters from the section above make sure to generate a new STL file for printing.
    - It is recommended to create separate STL files for the lid and base individually, as this will avoid accidentally printing the lid and base as one solid object
    - To create an STL file from the Editable Fusion 360 CAD model:
        - Right click on the lid/base component in the Design History Tree
        - Select "Save As Mesh"



        - In the pop-up menu that appears, configure the file settings as desired. We have found success using the settings below. Note: ensure the "Unit Type" matches the units used in the 3D printer slicer software.



- Click "OK" when satisfied. Name the STL file and save where preferred
- Remember to create two STL files total: one for the lid and one for the base

- **Printer Settings :** In your 3D printers slicer software, ensure to print with at least **6 perimeters and 40% infill**. This was found through research and rigorous testing detailed here. It is also important to print **without supports** for high quality threads. If supports need to be used, it is recommended to remove them as soon as the print completes to avoid the supports from hardening and binding to the threads.
  - It is important that the printer does not run out of filament halfway through the printing process, as this introduces a leaking point, found through experience. The default given STL file uses approximately 834g for the base, meaning you must start the print with a **full roll of filament.**
- **Node Insert :** A node insert can be printed separately to keep the node in place during deployment. See Section 3.2. Notches are printed into the enclosure itself, with allocated space underneath to allow for cable management/gathering.

2.2.6. Insert Cable Glands

Once you have an enclosure printed the next step is installing cable glands. See figure 3 below for a sample final result.

- **Installation :** Simply thread the gland through the holes configured at the bottom and seal with a locknut on the other end. For watertightness, ensure the glands are tightened firmly. If not tightened sufficiently the glands won't be waterproof.
- **Sealing (Optional) :** Apply aquarium silicone sealant around the interface of the cable gland and the 3D printed surface for additional protection.

Figure 4: Sample cable glands after installation (w/ sealant).

2.2.7. Sealant Application

For enhanced durability and waterproofing, apply a silicone sealant over all surfaces of the enclosure. Two recommended options are:

- **509 Aquarium ASI Silicone Sealant (left):** This sealant is thick and effective but harder to apply. It may need to be diluted for easier application and takes about 24 hours to cure.
- **ECOFLEX Ceramic Quick Coat (right) :** This is a spray-on sealant that is easier to apply but less durable. Apply multiple generous coats, at least 3, buffing thoroughly with a towel each time and then let it cure for 2 hours.
- **Safety Precautions :** Always follow safety guidelines detailed on the bottle or online while handling chemicals.

2.2.8. Deployment

- **Install O-ring :** Lubricate the procured o-ring with soapy water or preferably a dedicated o-ring lubricant, then simply place the o-ring inside its groove. Ensure the groove is smooth and as clean as possible.
- **Lubricate Threads (Optional) :** Using the same lubrication method as above, optionally lubricate the threads before screwing on the lid as tight as possible.
- **Test Enclosure :** Although iterations of this print have lasted for a week submerged under water, 3D printing can be affected by many factors which can ultimately affect the

waterproofness of the enclosure. It is recommended to test your fully assembled enclosure with paper towels, for a week, before using it with your ENTS node.

After all of these steps have been completed your enclosure is ready for outdoor deployment!

3. Common Components

3.1. Cable Gland Options

Cable glands are essential for securing cables within the enclosure while maintaining waterproofing. Table 3 outlines some commonly used cable gland options and for convenience table 4 highlights cable diameters of commonly used cables:

Table 4: Cable gland comparison

Cable Gland	**WISKA ¼" NPT**	**TE Connectivity M12 1.5**	**Polycase CG-30**
Cable Diameter Range	3-7 mm	3-6.5 mm	2.921-6.34 mm to 21.972-32.004 mm
Thread Length	15 mm	15 mm	8.128mm
3D Print Hole Diameter	14.138 mm	12.6 mm	12.01mm
Locknuts	¼" NPT Locknut	M12 1.5 Locknut	Included

Table 4: Standard Cable Sizes

Cable Type	USB	LoRa	Terras-12
Cable Diameter	3.15mm - 4.5mm	2.5mm	0.165mm

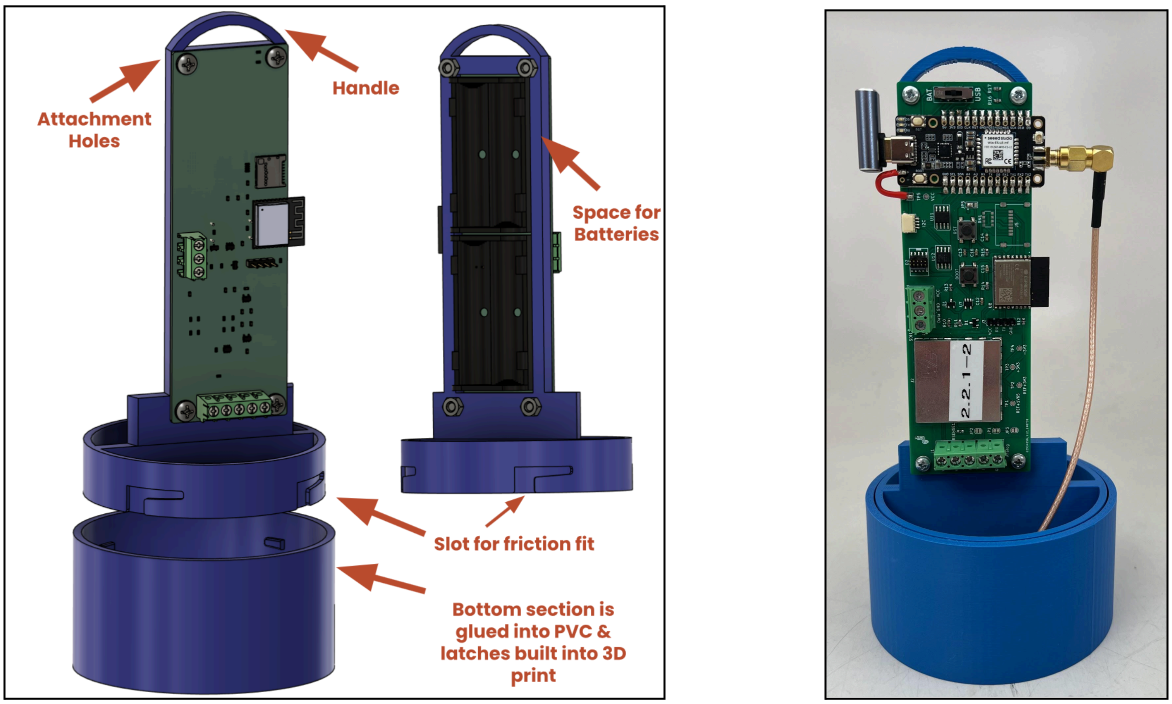
While table 3 highlights where to get a couple standard cable glands, ultimately the user can purchase from their preferred vendor as long as they meet certain guidelines, outlined below:

- Thread length over 10mm (for 3D printed) or
- Proper cable diameter range for specific cables being used
- Rated to IP68 Standard
- Either comes with locknut or ensure a compatible locknut can be procured

3.2. Node Insert

To support and position the ENTS node inside of each of the enclosures, a 3D printed insert is used, as seen in Fig.4 below. The insert consists of a cylindrical base and a vertical top with clearance holes at the corners to attach to the node itself with standard M3 nuts and screws. The bottom base has 4 notches that lock into the slots of the top component, when the top component is inserted concentrically and rotated clockwise. To unlock simply twist the top component counter clockwise. The insert can be printed in any material, typically PLA.

- **Printing :** With the provided STL files the insert can be printed for the given enclosure. This can be printed in any material, typically PLA, with any settings. At least 25% infill is recommended and supports are necessary for strength.



(a) (b)

Figure 5: Annotated insert diagram (a) and printed insert with attached node (b)

PVC Enclosure: The PVC use case requires printing both the base and twist lock top. The STL file can be found in the repository as “Twist Lock Insert (PVC) Inner/Outer Ring”. The base is then glued, using super glue designed for plastic or cyanoacrylate, to the flat end cap at the bottom of the closure after cable gland installation. The additional space and loft provided by the base allows you to store and pass in extra cables to the cable glands and helps with overall cable management of the enclosure.

Printed Enclosure: The printed enclosure use case requires printing only the twist lock top. The STL file can be found in the repository as “Twist Lock Insert (3D) Inner Ring”. The print enclosure already comes with the stubs necessary to just twist and lock the top in, once aligned.

3.3 Cost Breakdown

Below is a breakdown of the overall costs of both enclosures.

Table 5: Total Costs of Both Enclosures

	3D Printed	PVC
	$24 - Filament	$33.3 - Individual Components
	$1.37 - O-Ring (5-Pack)	$7.68 - 4 Cable Glands $1.5 - 4 Cheaper Cable Glands
	~ $1 - Silicone Sealant ($20 Upfront)	
	$7.68 - 4 Cable Glands (With Locknuts) $1.5 - 4 Cheaper Cable Glands	
Total:	**$27.87**	**$34.8**

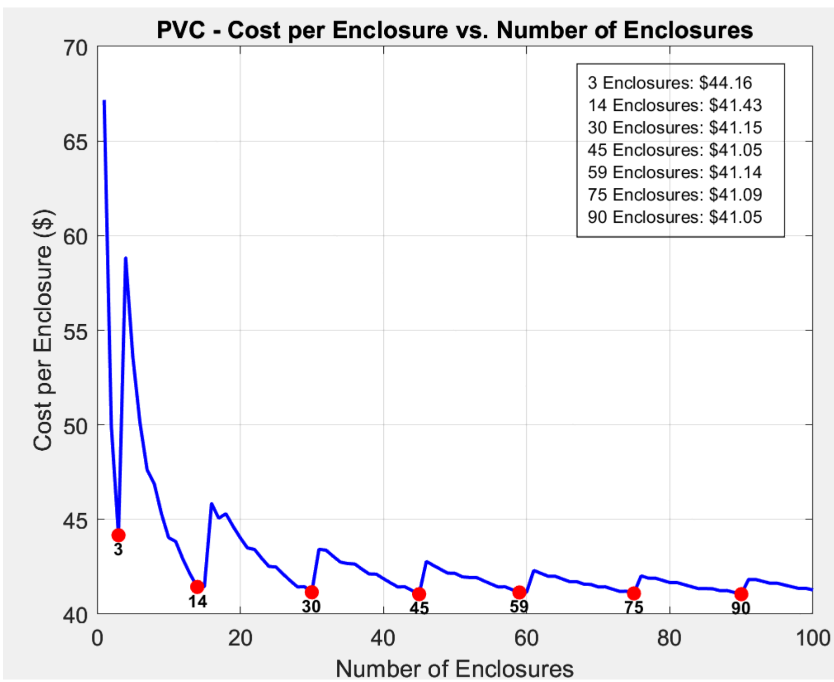


Figure 6: Graph depicting Cost per PVC Enclosure vs Number of PVC Enclosures. Note: exact prices may vary depending on components used, supplier, shipping, time of purchase, etc.

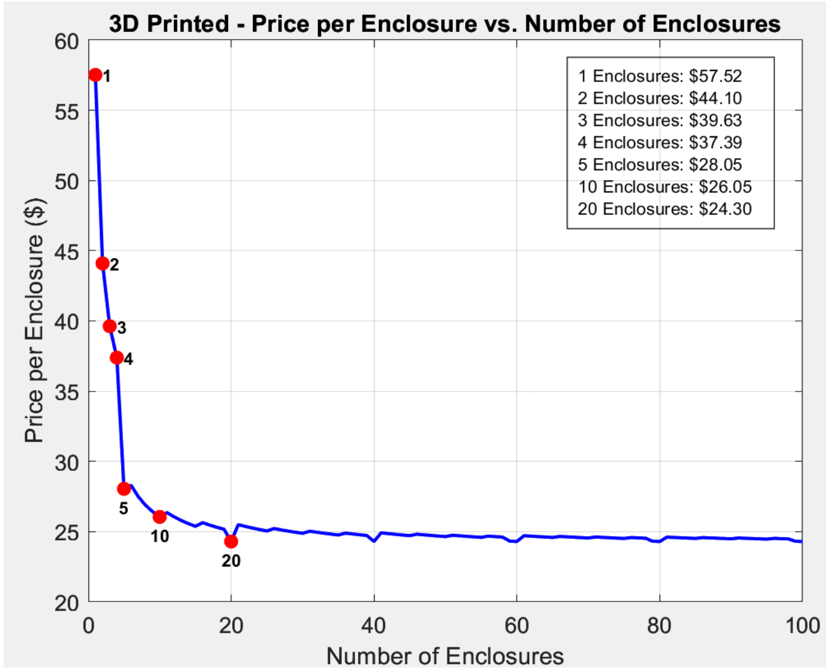


Figure 7: Graph depicting Cost per 3D Printed Enclosure vs Number of 3D Printed Enclosures. Note: exact prices may vary depending on components used, supplier, shipping, time of purchase, etc.