MAKING BUILDINGS GREENER

Identifying building trades that need support to successfully implement airtight residential building envelopes

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DISCLAIMER

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organisations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This Project was conducted under the mentorship of the Township of Langley staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of the Township of Langley or the University of British Columbia.

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1. Introduction

The Township of Langley has adopted the BC Energy Step Code (BC ESC) for residential buildings. The Township requires all applicable buildings to be built to Step 3, starting January 1st, 2022, and the Upper Steps, 4 and 5, to follow. The BC ESC has airtightness requirements measured in air changes per hour (ACH) for Part 9 buildings. As the required Step increases, airtightness requirements also increase. The final Step requires an air change rate that is 67% lower than Step 2, the first Step with an ACH target. With the adoption of BC ESC, gaps have emerged between the Step Code's requirements and construction trades' understanding of how to build airtight envelopes. An airtight building envelope is a system that separates exterior and interior environments and consists of an air barrier layer that limits air leakage into and out of the conditioned space. Airtight envelopes reduce heat loss, outside noise penetration, wind-driven rain penetration and allow for better indoor air quality. By limiting air leakage and reducing heat loss, air barriers contribute to decreasing energy consumption, reduced GHG emissions and lower operational costs.

In order to effectively build airtight envelopes, different segments of the construction industry need to know how their work will impact the overall effectiveness of the air barrier. In addition to design strategies, the success of achieving Upper Steps' airtightness requirements relies on the multi-step construction process and construction trades' capacity. Each relevant trade will have different degrees of understanding and experience in the implementation of an airtight envelope. Where there are capacity gaps in any given industry group, the overall chance of achieving success with the implementation of a high-performance envelope might be dramatically reduced. In addition, failure to achieve airtightness at the final blower test can result in additional costs through labour, materials, design, and even mechanical retrofits to address higher than anticipated air leakage rates after the fact. In other words, identifying trades that would most benefit from information on where they can improve their practices and at what stage(s) will benefit both the construction industry and the general public.

An industry-wide online survey, consisting of general air barrier knowledge questions, technical questions, and demographics questions, was created to support the industry in achieving and exceeding airtightness requirements with the help of the Township of Langley - Green Buildings Team. The technical questions target construction trades, including drywallers, window/door installers, framers, insulators, plumbers, HVAC contractors, electrical contractors, cladding installers, and general contractors separately. The survey is built such that once it is completed, gaps in knowledge, practice, and issues with the distribution of responsibilities will be revealed for each trade.

The ultimate goal of this Project is to improve construction practices of Part 9 and Part 3 residential buildings to successfully achieve airtight buildings in the Township of Langley. The report will inform the Township's education programs such as the Builder Forum Series and other education-based vehicles. The results will be shared publicly and intends to bridge overall gaps in practice. Overall, this report will help BC builders meet the BC Energy Step Code requirements, a key step in the path towards Net Zero Energy Buildings in British Columbia (BC). Finally, the development community can use these findings to improve their construction methods, meet Step Code targets more predictably, and create more

comfortable homes. Thus, this report can act as an exceptionally insightful tool adding value to the construction process.

1.1 Objectives

Project objectives are outlined as:

1. **Research:** Identify building envelope components and assemblies (primarily in Part 9 buildings) and determine which trades interact with these components. These trades will be contacted for the survey. Research and determine how each trade will be contacted with the help of Township of Langley mentors.
2. **Stakeholder Survey:** Prepare a questionnaire with mostly dichotomous questions for trades to identify the gaps in understanding of how to build (and not damage) a high-performance and airtight envelope. The survey will use cascading logic to gather increasingly detailed, trade-specific information.
3. **Analysis and Report:** Prepare a matrix consolidating each trade and their capacity profile against the selected building envelope components (and other systems intersecting with them)/ strategies. An accompanying report will summarize the results of the survey as well as gaps and opportunities within industry groups.

1.2 Scope

A summarized scope of the Project is displayed below:

a) In Scope:

- Identify building envelope components and which trades can influence them.
- Conduct research and identify the envelope components for Part 3 (only residential) buildings to add up to identified Part 9 buildings' envelope components by BC Housing.
- Identify industry organizations that can support reaching out to members of the building industry. Determine how each building industry member will be contacted for the survey.
- Prepare a questionnaire with mostly dichotomous questions for the building industry to identify the gaps in understanding of how to build a high-performance envelope and at what stage of construction these trades interact with the building envelope. The survey will use cascading logic to gather increasingly detailed trade-specific information.
- Prepare a matrix made up of each construction industry actor and their capacity profile against a large selection of envelope components and strategies.
- Prepare a report summarizing the survey results, including an analysis of gaps and opportunities within the industry groups (for example, which industries are at higher risk of compromising the success of the envelope, and which industry groups would benefit by being brought in earlier into the design and construction process)

b) Out of Scope:

- Institutional, commercial, and industrial types of Part 3 buildings are excluded.

2. Survey Design Methodology

The target participants of the survey are drywallers, window/door installers, framers, insulators, plumbers, HVAC contractors, electrical contractors, cladding installers, general contractors, other trades that work or supervise on a construction site. Those construction trades were chosen because of their role in building and preserving the air barrier during construction.

Relevant stakeholders operating in the Township of Langley and the community of builders that the Green Buildings Team has developed over the years were contacted to participate in this survey. In addition, a list of associations/organizations related to the building industry was collected as a part of the Project. Those associations were then contacted by email and phone to inform them of this Project and garner their support to share the survey with their members. All the data from the participants was collected anonymously.

The survey consisted of general air barrier knowledge questions, technical questions, and demographics questions (Appendix A). The general knowledge questions each trade's familiarity with different air barrier materials, sealants, and approaches with multi-choice options. The technical questions are mainly comprised of dichotomous questions about which kind of work each trade is responsible for when it comes to building a continuous air barrier. Finally, the demographics questions help understand where and on what type of projects the participants work. After the questions were prepared, the Communications Department of the Township of Langley built the online survey in SurveyMonkey.

2.1 Part 9 and Part 3 Wood-Frame Residential Building Air Barrier Carriers

Building envelopes are comprised of foundations, walls, roofs, windows, doors, and other elements that penetrate the envelope. The key role of a building envelope is to separate interior and exterior environments to provide human comfort. For this purpose, a high-performing envelope functions as an air barrier, water-resistive barrier, a water-shedding surface, a vapour retarder and as thermal insulation. These functions must be ensured by each assembly of the envelope as well as interfaces and penetrations. This Project only focuses on airtightness.

Air barriers are not structural elements. Therefore, they must be fixed to a solid supporting system which is either the exterior or interior sides of the building shell. The air barrier can also be installed on surfaces dividing different units in a multi-unit building. In that case, an air barrier layer may also be needed in interior walls and ceilings. It is also common to build the air barrier layer on the ceilings as an alternative to the entire roof in Part 9 buildings. In that case, the air barrier would be wrapping around the living spaces only instead of wrapping the building. Air barrier carriers of Part 9 and Part 3 wood-frame residential buildings are grouped based on the envelope details from the BC Housing envelope guides listed below:

- "Building Envelope Guide for Houses: Part 9 - Residential Construction," Second Edition (BC Housing, 2020) – This guide refers to the minimum building standards for both design and construction phases of the building envelopes for the buildings under Part 9 of the British

Columbia Building Code (BCBC) 2018 and the Vancouver Building By-Law (VBBL) 2019. It lists options for the building envelope details for different air barrier approaches, including the interior air barrier method -sealed polyethylene approach (Figure 1), and the exterior air barrier method -synthetic sheathing membrane approach. Details are modelled and depicted in 3D format, then shown as a step-by-step installation manual.

- "Building Enclosure Design Guide: Wood-Frame Multi-Unit Residential Buildings," Second Edition (BC Housing, 2020) – This guide focuses on present building science approaches and the best practices for designing and constructing the building envelope of multi-unit, wood-frame residential buildings. After permission is granted for wood-frame construction in five- and six-storey buildings in BCBC 2006 and VBBL 2007, increased energy performance requirements are included in BCBC 2018 and VBBL 2014 for those wood-frame buildings. It provides samples of details (Figure 2), assemblies, components and materials used in Canada for energy-efficient building envelopes of taller wood structures. The details are mostly depicted in 2D technical drawing formats, with the annotations of each layer below.

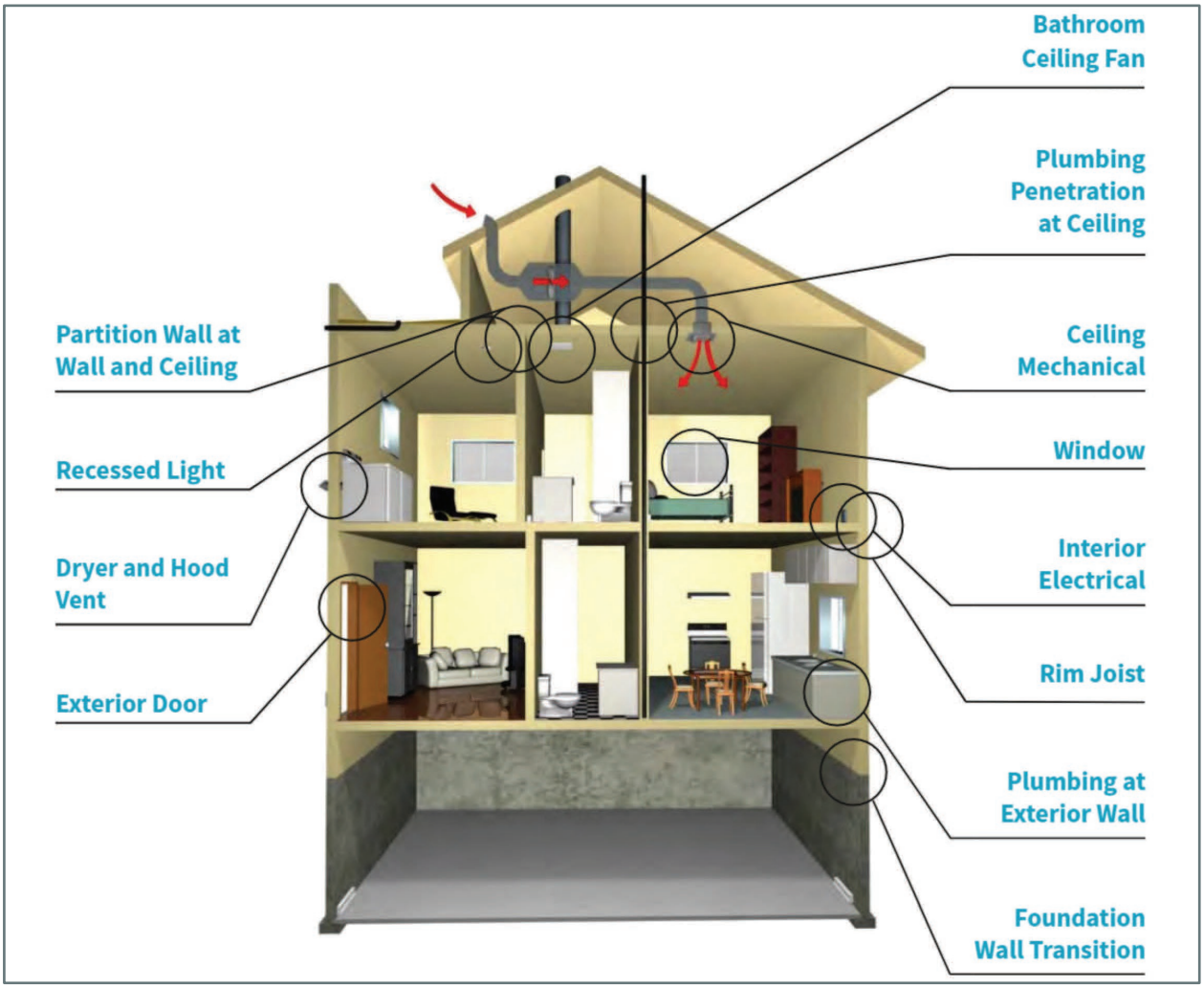
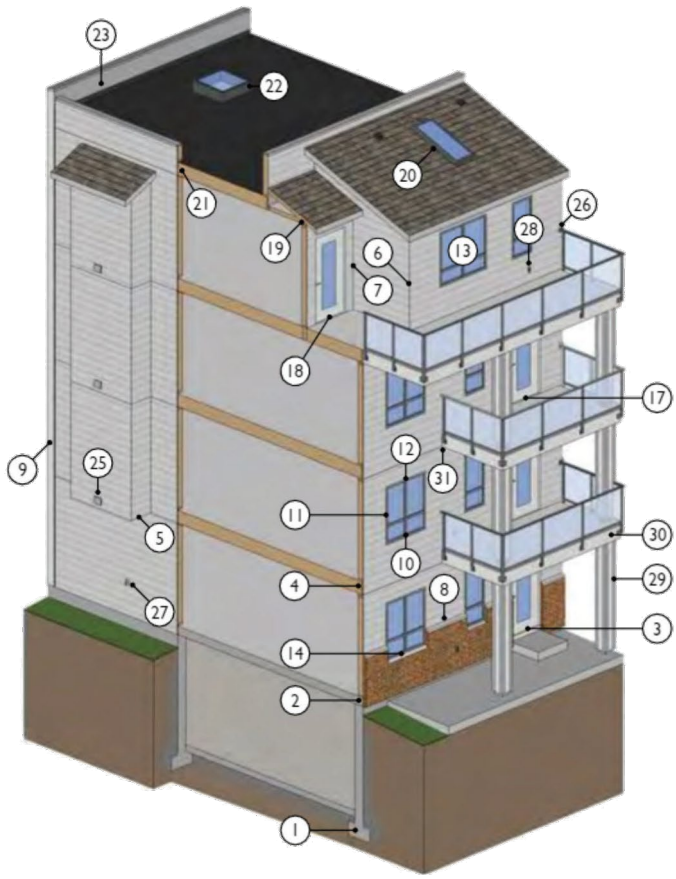


Figure 1 – Detail locations of sealed polyethylene approach on Part 9 buildings.

Retrieved from Building Envelope Guide for Houses: Part 9 - Residential Construction, Second Edition (BC Housing, 2020). Page numbers shown in the original diagram were removed by the author as they refer to pages in the originating document.



Title
Concrete Foundation Details
Detail 1 – Foundation Wall at Slab Thermal Insulation
Detail 2 – Base of Wall/Foundation
Detail 3 – Door Sill/Concrete Deck
Wall Details
Detail 4 – Rim Joist
Detail 5 – Wall/Cantilevered Floor
Detail 6 – Exterior Corner
Detail 7 – Interior Corner
Detail 8 – Cladding Transitions
Detail 9 – Fire Wall at Exterior Wall
Window and Door Details
Detail 10 – Window Sill
Detail 11 – Window Jamb
Detail 12 – Window Head
Detail 13 – 3D Window Installation Sequences
Detail 14 – Window Sill – High Differential Movement
Detail 15 – Door Sill – Cantilevered Balcony
Detail 16 – Base of Wall – Cantilevered Balcony
Detail 17 – Door Sill – Supported Balcony
Detail 18 – Door Sill – Roof Deck
Roof Details
Detail 19 – Water Shedding Roof/Wall
Detail 20 – Water Shedding Roof/Skylight
Detail 21 – Waterproof Membrane Roof/Wall
Detail 22 – Waterproof Membrane Roof/Skylight
Detail 23 – Waterproof Membrane Roof/Firewall
Detail 24 – Roof Deck Divider Wall
Penetration Details
Detail 25 – Wall Duct Penetration
Detail 26 – Railing Attachment at Wall
Detail 27 – Pipes
Detail 28 – Electrical Fixtures
Exterior Elements
Detail 29 – Column Detail
Detail 30 – Balcony Edge
Detail 31 – Balcony Edge/Wall 3D Sequence

Figure 2 – Locations of details on a wood-frame multi-unit residential building.

Retrieved from Building Enclosure Design Guide: Wood-Frame Multi-Unit Residential Buildings, Second Edition (BC Housing, 2020). The list of details on the right side, was named as "Table 6-1 List of Details" in the original guide, is simplified, and juxtaposed with the image in Figure 2.

The air barrier carriers and other systems that penetrate the air barrier on those carriers are grouped by their function and their engagement with different construction trades. Those groups also accommodate the technical questions about air barriers in the survey that are being asked to separate construction trades depending on their responsibilities on site, which will be explained in Section 2.2. The groups are listed as:

1. Foundations
2. Floors
3. Walls
4. Ceilings
5. Roofs
6. Windows/Doors
7. Mechanical
8. Electrical
9. Plumbing

Foundation questions include details about sealing the air barrier at slab/wall transitions and joints between the foundation wall and the bottom wall plate. The floor questions are about installing the air barrier continuously around the rim joists, where they are exposed, whether they overlap with the envelope or pass through the envelope to form balconies and decks. The wall, ceiling and roof questions are directly asking if the related trades install a continuous air barrier that is lapped and sealed. The questions about windows and doors include details about sealing framing connections, installing the exterior air barrier at the sill/jamb/head transitions before placing the windows and doors. The following questions in this category are on the sealing around the windows and doors after they are placed and installing the interior air barrier. Questions about the mechanical systems interrupting the air barrier include using airtight mechanical boxes for HVAC equipment such as bathroom fans and exhaust fans; sealing the penetrations inside and outside of those boxes; then installing the air barrier around the mechanical equipment. Further, it is also asked whether mechanical ducts' joints are being sealed or not. Similarly, for electrical equipment interrupting the air barrier layer, questions are about using airtight electrical boxes for recessed lights and plugs; sealing the penetrations inside and outside of those boxes; then installing the air barrier around the electrical equipment. Lastly, questions about the plumbing systems include applying a sealant, placing a "+" or semi-circle cut gasket and installing an air barrier layer around the pipes on airtight assemblies to form a continuous air barrier. In addition, a best practice question is added, which is sealing around the metal flashings above any fenestration, mechanical, electrical, and plumbing systems.

The master list of trades' questions (Appendix B), explanatory figures for the trades' questions (Appendix C) and survey questions preparation diagram (Appendix D) can be found in the Appendices Section.

2.2 Related Trades in the Construction Industry

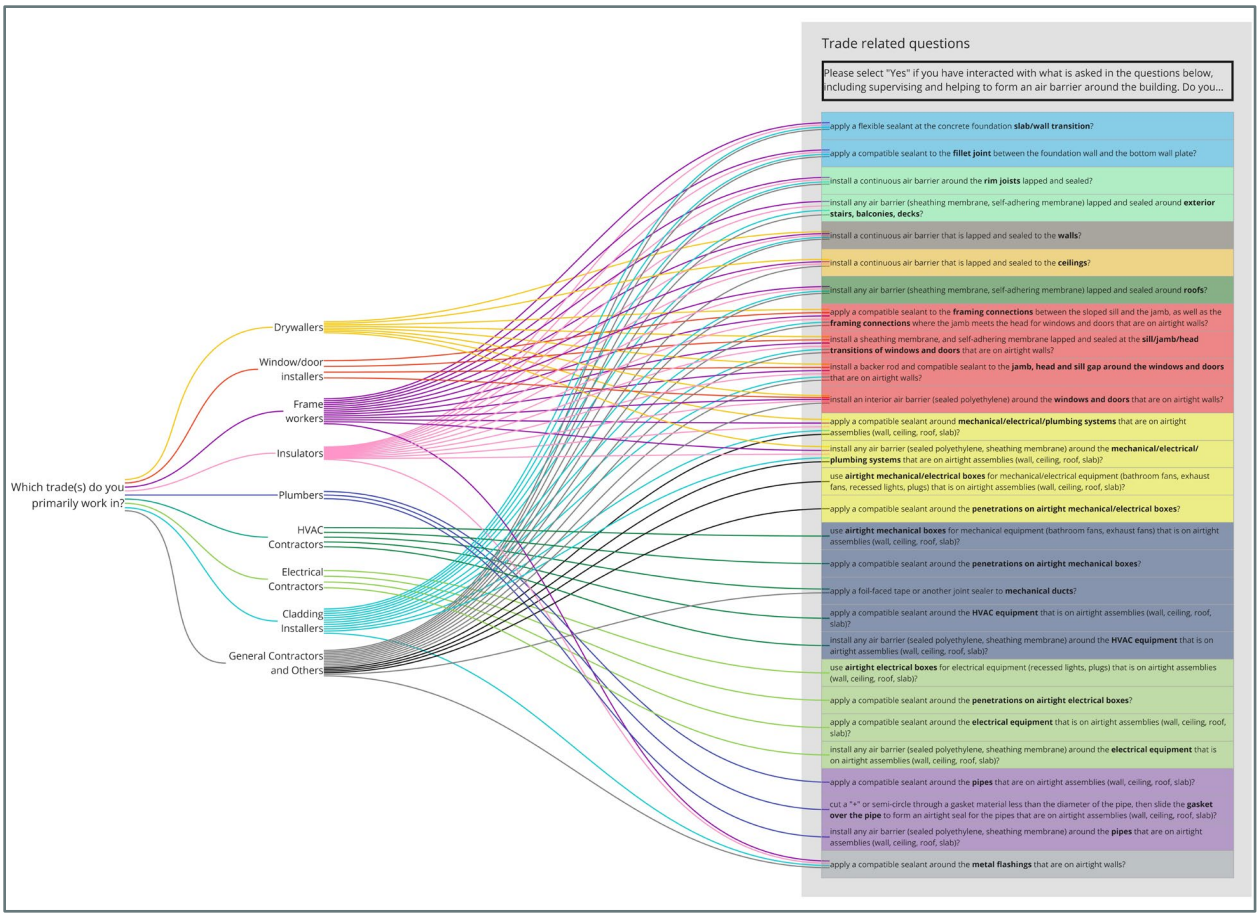


Figure 3 – Trade related questions network.

Construction is a multi-step process where each trade working on site has different expertise and responsibilities. Since air barrier requirements are relatively new in BC, the lines of duties of installing the air barrier are still blurry in the industry. The purpose of grouping the questions in Section 2.1 is also to specify which set of work is related to which construction trade so that all the questions will be asked to the relevant trades. For example, questions about fenestration systems are asked to drywallers, window/door installers, frame workers, insulators, cladding installers, and general contractors only. This is because the air barrier around the windows and doors might be installed by those related trades. The plumbers, HVAC contractors and electrical contractors are exempted from the fenestration questions. Figure 3 shows the network of trade related questions and Figure 4 shows the full table of the construction works grouped in the previous section and their related trades.

Trades / Groups	Foundations	Floors	Walls	Ceilings	Roofs	Fenestration	Mechanical	Electrical	Plumbing
Drywaller			*	*		*	*	*	*
Window/Door Installers						*			
Frame Workers	*	*	*	*	*	*	*	*	*
Insulators	*	*	*	*	*	*	*	*	*
Plumbers									*
HVAC Contractors							*		
Electrical Contractors								*	
Cladding Installers	*	*	*		*	*	*	*	*
General Contractors	*	*	*	*	*	*	*	*	*

Figure 4 – Trades' engagement table.

3. Analyses of Survey Results

The survey received 232 responses and was available from Monday, June 21st, to Monday, July 5th, 2021. The target participants had already been identified as people who might build or interact with the air barrier layers, and those actively work on site, such as labourers and supervisors. Therefore, 8 participants working as architects, energy advisors, a designer and a manufacturer's representative were removed from the collected data and omitted in the results.

To increase the completion rate of the survey, questions 8 and 10 were mandatory with the others being optional. Meaning, the participants were not allowed to pass on the next question without answering these particular questions. These questions were also the only questions that used skip logic to direct participants to the next question depending on their answer. The numbers of people who answered and skipped each question are presented under each question. The survey results are examined under three main groups below: General Questions, Technical Questions, and Demographics Questions.

3.1 General Questions

General questions test the participants' knowledge about air barrier features, materials, sealants, and approaches.

Question 1: In your opinion, how important is the airtightness of a building on average in your everyday work?

Answered: 220

Skipped: 4

Figure 5 shows the results of Question 1. While 46.4% of the participants believe that the air barrier is very important, 5.9% of the participants believe it is unimportant. The options to this question are ranked according to a 5-point Likert Scale to understand the participants' opinion about the importance of the air barrier. Given the scale from "0=very unimportant" and "4= very important", the weighted average is 3.02. This average shows that most of the people working on site understand the importance of the air barrier.

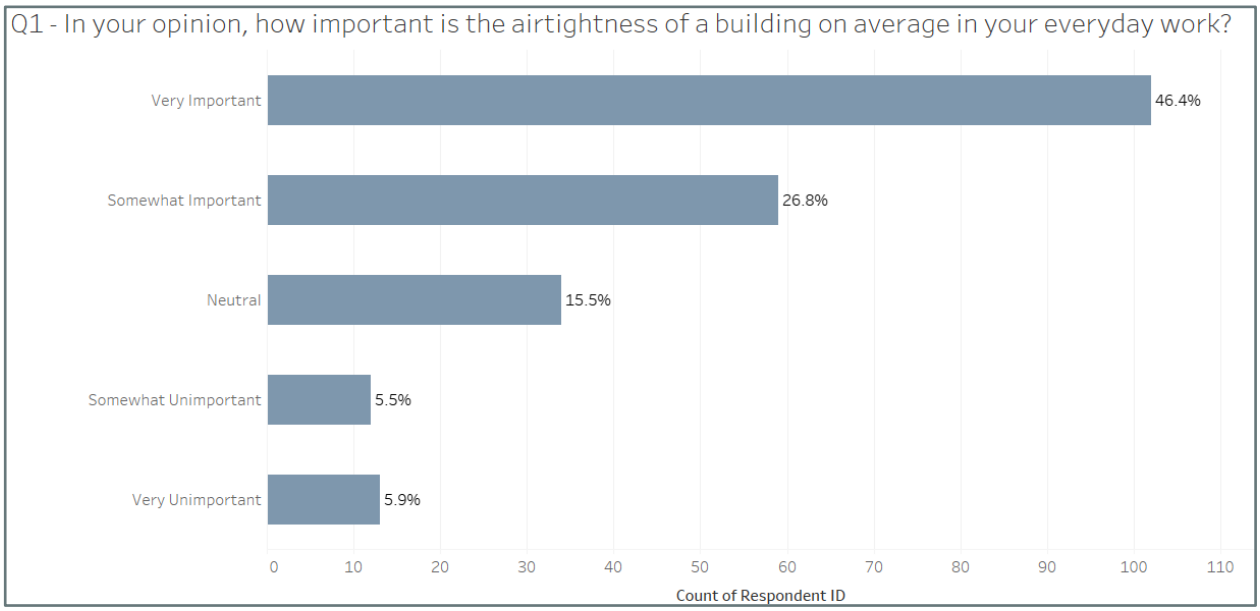


Figure 5 – Question 1 results - count of respondents for each answer.

Question 2: Which of the following are requirements of a building's air barrier? (Select all that apply)

Answered: 161

Skipped: 63

Figure 6 shows the results of Question 2. The correct answer is all the options. According to the BC Energy Step Code: Builder Guide (BC Housing, 2018), an effective air barrier must be air impermeable (less than 0.02 L/s·m2 at 75 Pa), continuous, durable, stiff, and strong. Approximately three-quarters of the participants who answered this question knew that air barriers must be air impermeable and continuous.

In addition, almost half of the participants knew that it has to be durable. However, only 18.6% of the participants know that air barriers must also be strong and stiff, and 7.5% of the people selected the option "I don't know." Strength and stiffness are significant features of the air barrier for it to last as long as the building does. This result shows us that the people responsible for installing the air barrier on site should be better trained on the installation features and the importance of the air barrier.

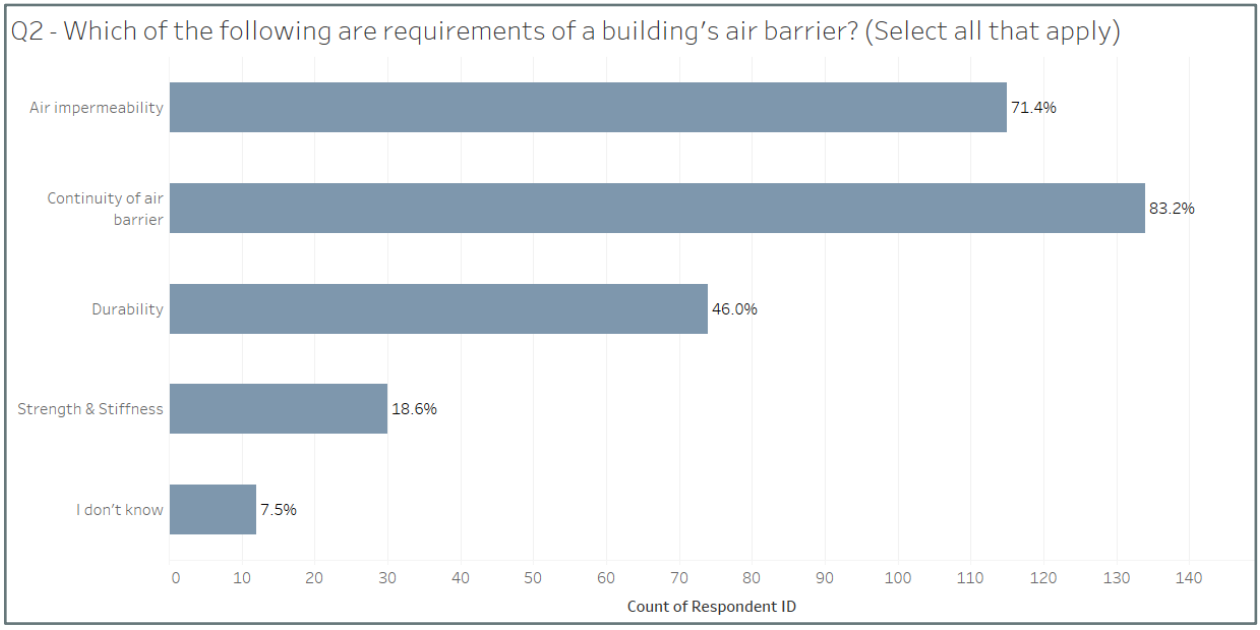


Figure 6 – Question 2 results - count of respondents for each answer.

Question 3: Which building materials can be considered airtight? (Select all that apply)

Answered: 162

Skipped: 62

Figure 7 shows the results of Question 3. The correct answer is all the options when the specific material is used with proper sealants, thickness, and lapping. It is not surprising that most of the participants are familiar with using spray foam insulation and polyethylene sheet as air barriers. Also, expectedly, the least known materials are plywood, breathable sheathing membrane and sheet metal. What is extraordinary with this result is the drywall, with its consideration rate of 32.1%. In Building Envelope Guide for Houses: Part 9 - Residential Construction (BC Housing, 2020), the airtight drywall air barrier approach is one of the two interior air barrier approaches, and there is a section with step-by-step details dedicated to drywall as an air barrier layer.

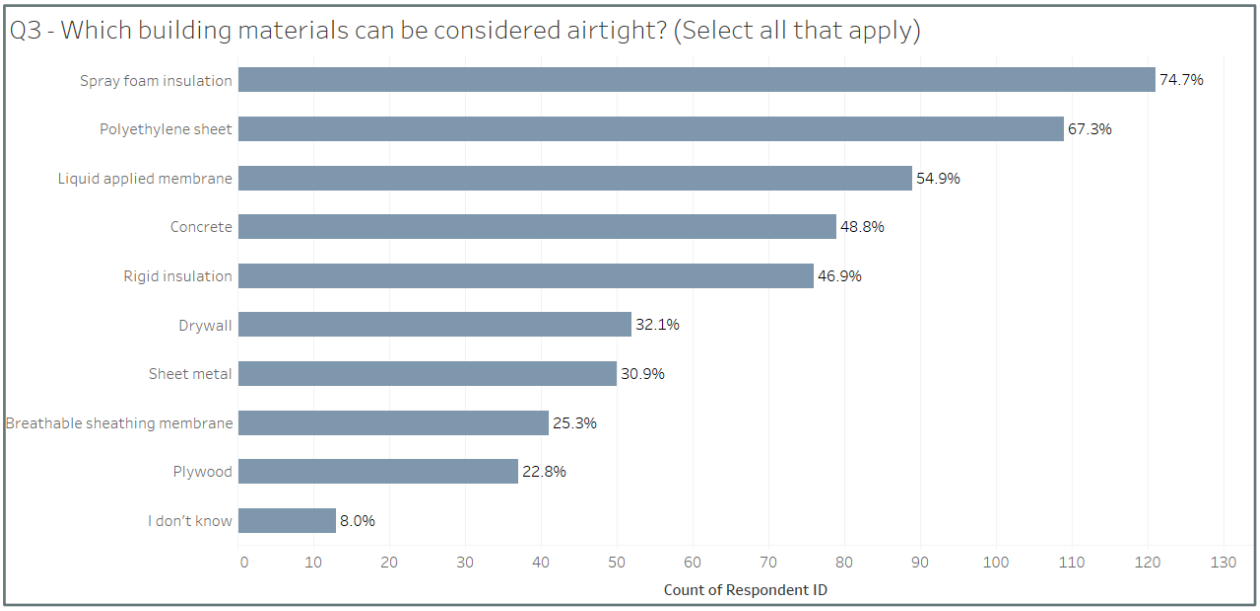


Figure 7 – Question 3 results - count of respondents for each answer.

Question 4: Which of these sealants can be used to seal the air barrier? (Select all that apply)

Answered: 162

Skipped: 62

Figure 8 shows the results of Question 4. The correct answer is all the options. The acoustic sealant is the most recognized sealant, with a rate of 68.9%. Interestingly, 4 out of 8 sealants in the options are known by less than 50% of the participants who answered this question.

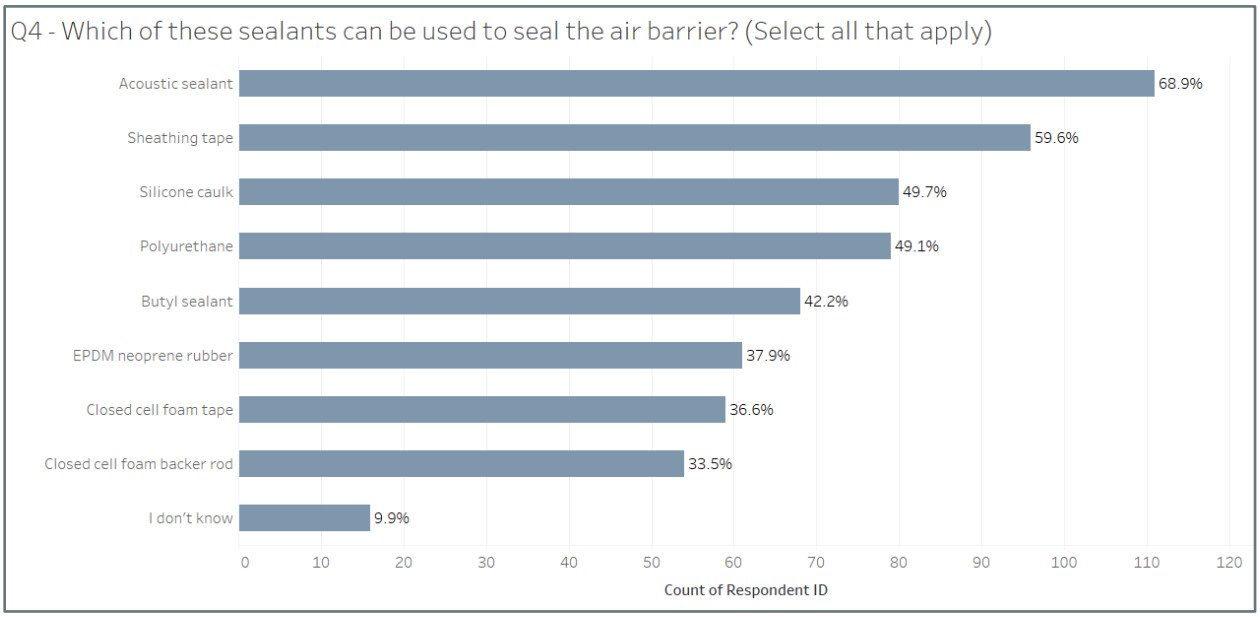


Figure 8 – Question 4 results - count of respondents for each answer.

Question 5: How familiar are you with the following interior and exterior airtightness approaches?

Answered: 162

Skipped: 62

Figure 9 shows the results of Question 5. According to the chart, the familiarity of the participants with different interior and exterior approaches is relatively balanced. Yet, it is possible to conclude that the construction trades are primarily familiar with the sealed polyethylene approach on the interior and mostly unfamiliar with the liquid applied sheathing membrane approach on the exterior. Figures 7, 8, 9 reveal that the construction trades working on site might need education on various air barrier materials, sealants, and installation approaches. This information might help to improve the rate of passing the door blower test in the first-time round.

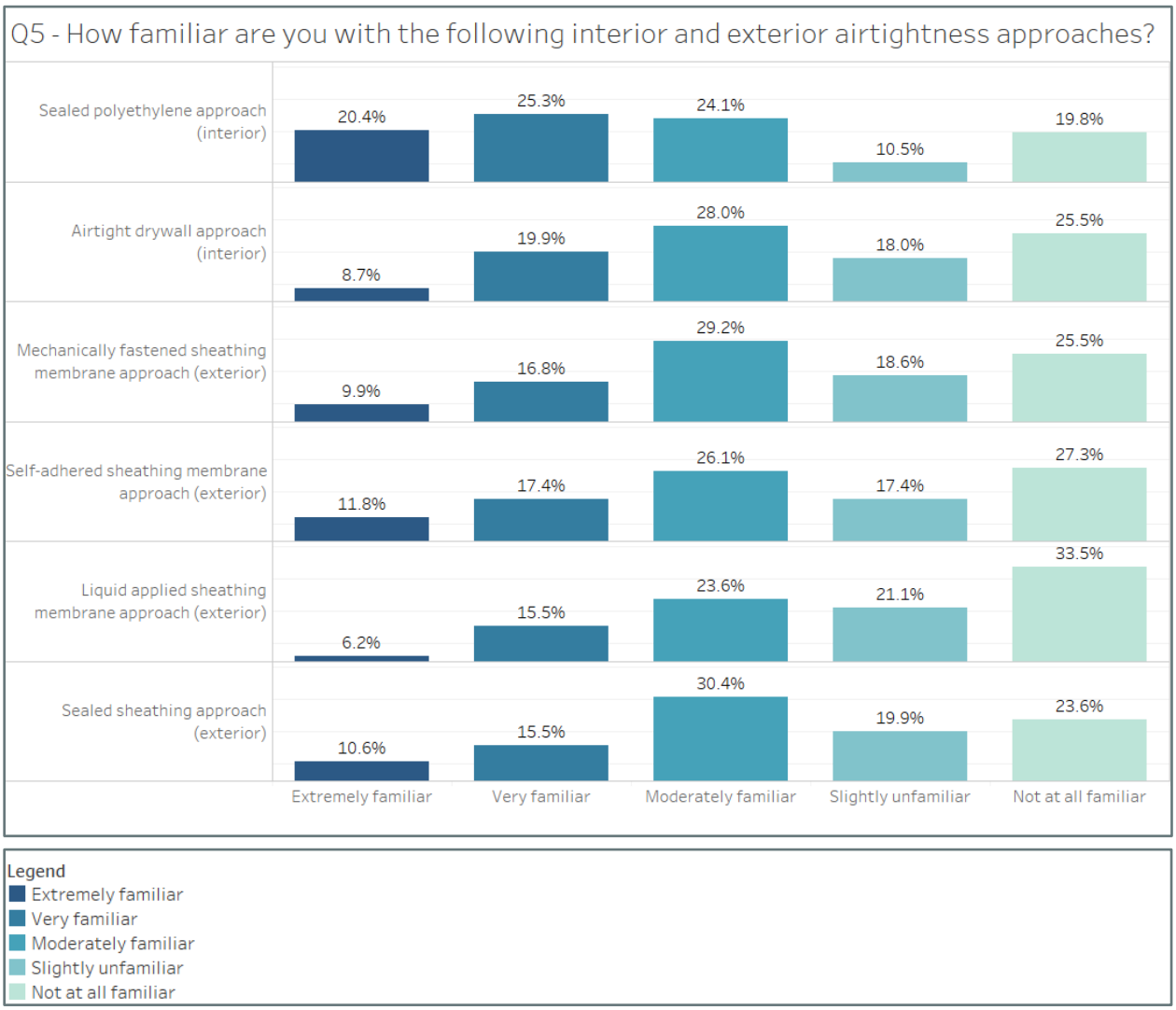


Figure 9 – Question 5 results - count of respondents for each answer.

3.2 Technical Questions

The technical questions are formed to evaluate different construction trades' responsibilities on building the air barrier. Effectively, the questions are asked to assess if they do the work and who they think should be doing the work.

Question 6: To your knowledge, who wraps the polyethylene sheet or sheathing membrane as an air barrier around the building? (Select all that apply)

Answered: 154

Skipped: 70

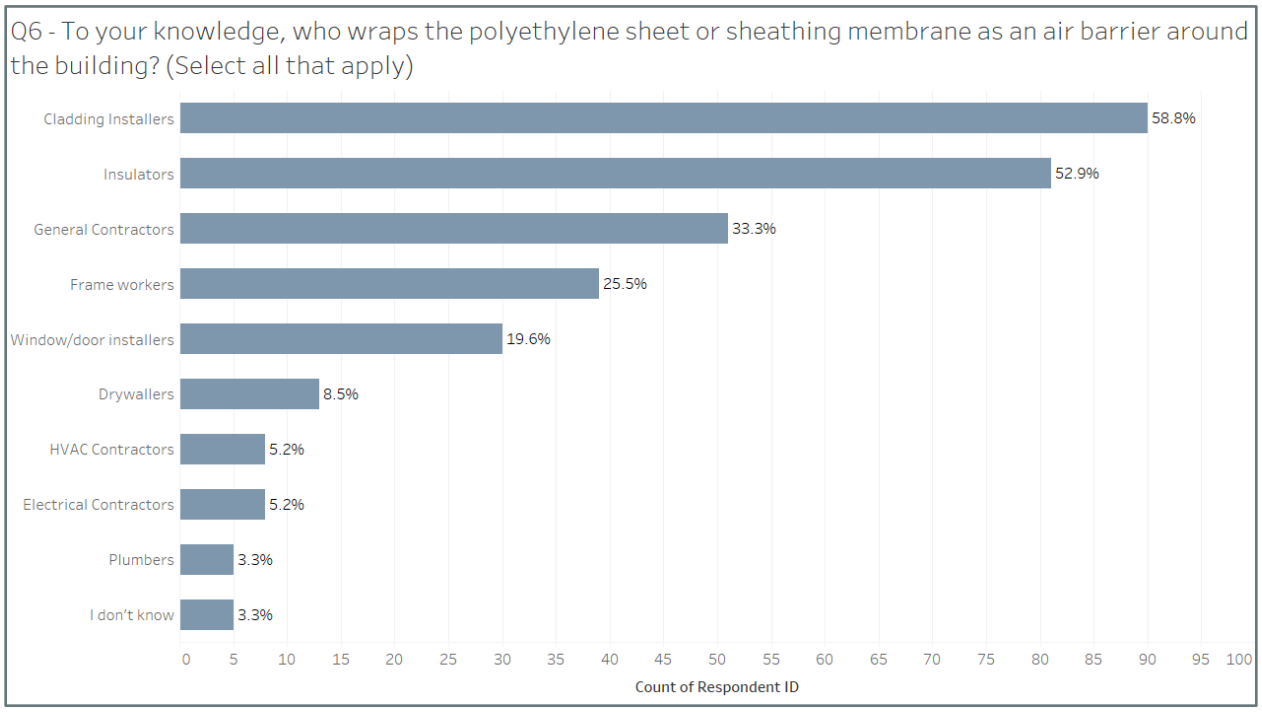


Figure 10 – Question 6 results - count of respondents for each answer.

Figure 10 shows the results of Question 6. More than half of the participants who answered this question suggested that cladding installers and insulators are currently the ones wrapping the air barrier.

Figure 11 shows the results of Question 6 with the breakdown of the trades who answered them. Details about the participants working in each trade can be found under Question 10. This chart shows that the greatest number of general contractors, HVAC contractors, electrical contractors, frame workers, drywallers, window/door installers claim that it is cladding installers and the insulators who install the air barrier around and inside the building, including themselves.

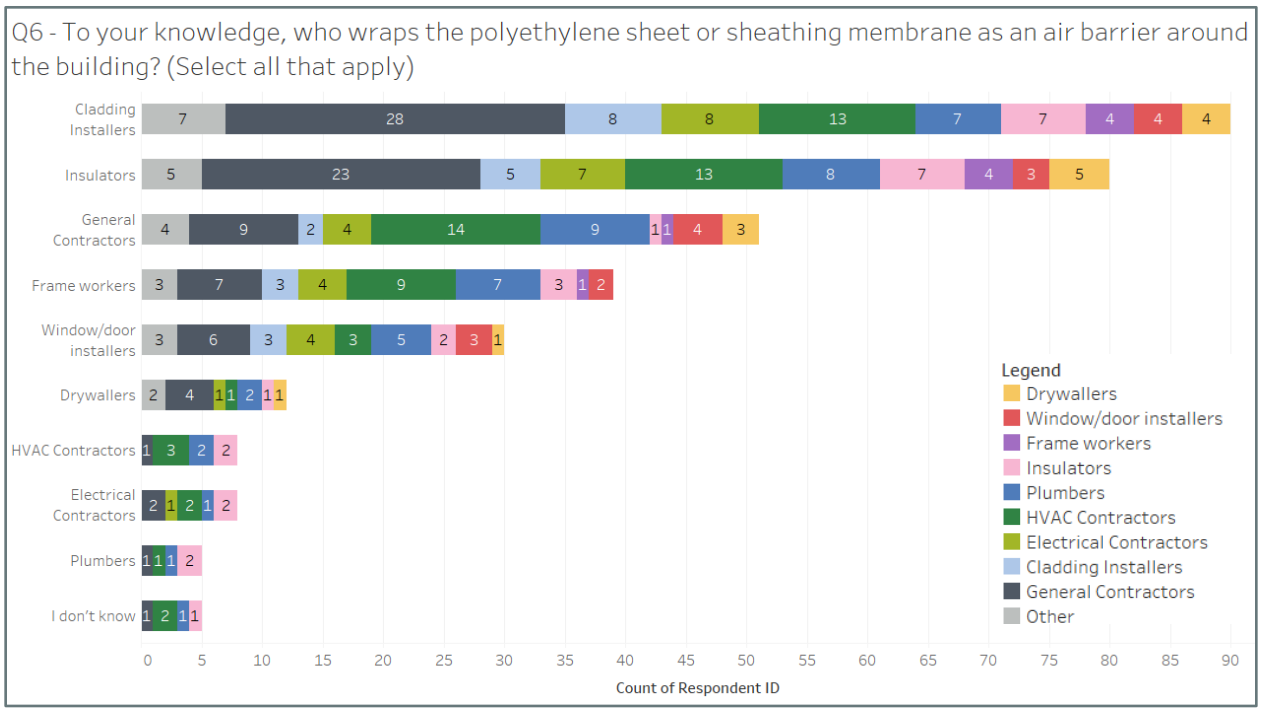


Figure 11 – Question 6 results - count of respondents for each answer and trade's breakdown.

Question 7: To your knowledge, who is/should be in charge of air barrier quality control on a construction site? (Select all that apply)

Answered: 154

Skipped: 70

Figure 12 shows the results of Question 7. This chart shows that 80% of the participants who answered this question agreed upon general contractors as the main responsible party for the air barrier quality control on a construction site. 21 participants also suggested the "other" option. 8 of those people reiterated that it should be anyone's responsibility to install the air barrier. 3 people proposed "building envelope consultants." 4 people provided the answers "building inspectors," "site supervisors," and "builders." 3 people recommended "air boss," "energy advisor," and "another third-party inspector." Lastly, 3 separate people implied "concrete workers," "masonry workers," and "roofers." The detailed list of each "Other" option suggested by the participants with the number of participants for each option can be found in Figure 13.

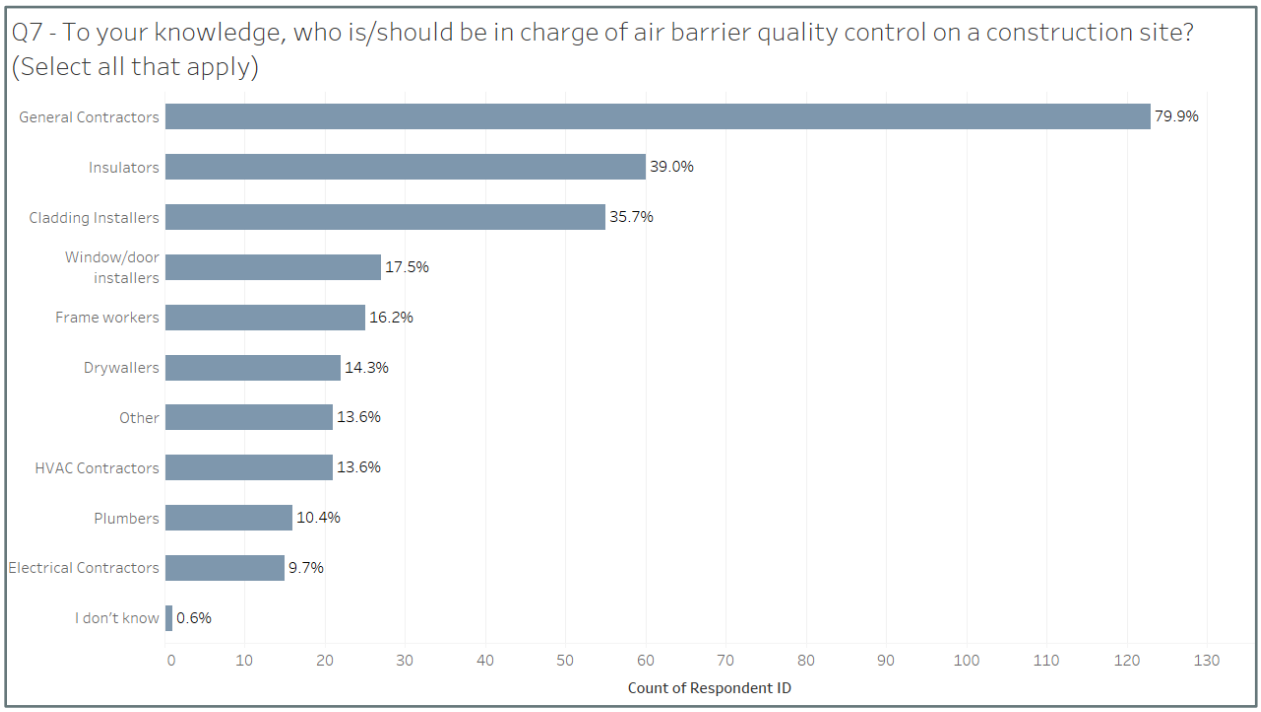


Figure 13 – Question 7 results - count of respondents for each answer.

"OTHER" OPTIONS	COUNT OF RESPONDENT ID
Anyone who penetrates the air barrier	8
Building envelope consultant	3
Building inspectors	2
Site supervisor	1
Builder	1
Air boss	1
Energy advisor	1
Third party inspector	1
Concrete workers	1
Masonry workers	1
Roofers	1
Total	21

Figure 12 – Question 7 results – the list of "Other" options with the count of respondents.

Figure 14 shows the results of Question 7 with the breakdown of the trades who answered them. Details about the participants working in each trade can be found under Question 10. According to the chart, most general contractors themselves agree that they should be in charge of the air barrier.

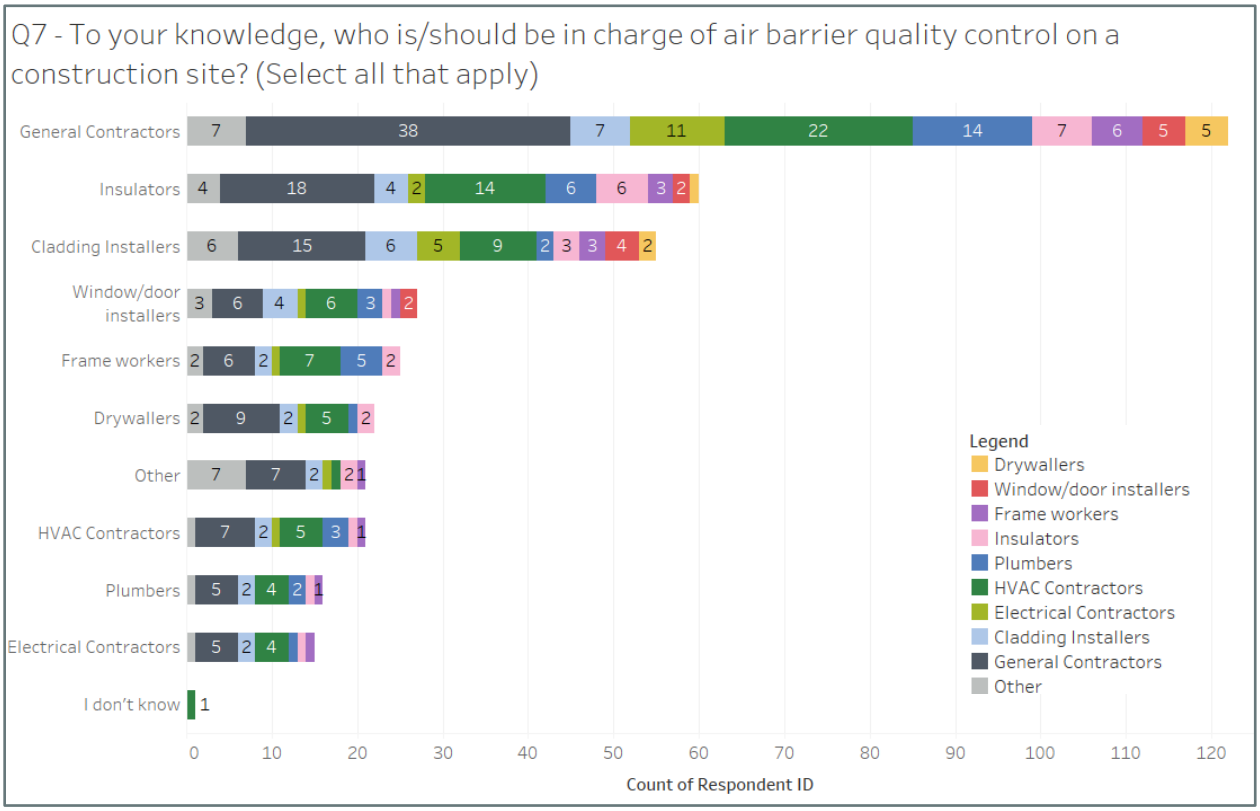


Figure 14 – Question 7 results - count of respondents for each answer and trade's breakdown.

Question 8: Do you coordinate with other trades to make the building airtight?

Answered: 158

Skipped: 66

Figure 15 shows the results of Question 8. This question was a mandatory skip logic question. Participants who answered "yes" were directed to the next question (Question 9), and the rest were redirected to Question 10. While 72.2% of the participants stated that they coordinate with other trades, 27.8% indicated otherwise. This might indicate that current air barrier practices are the result of collaborative on-site work.

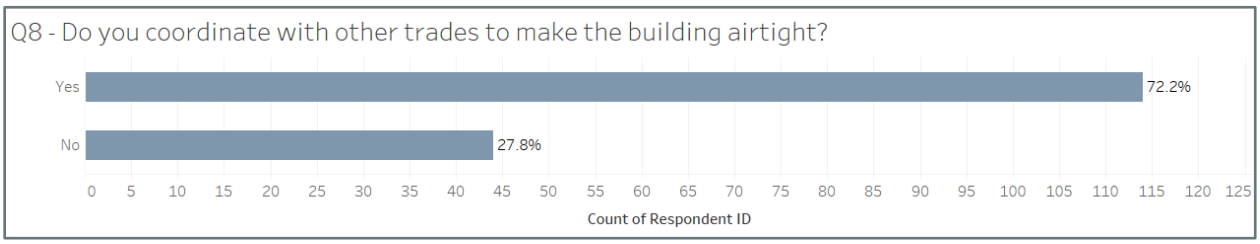


Figure 15 – Question 8 results - count of respondents for each answer.

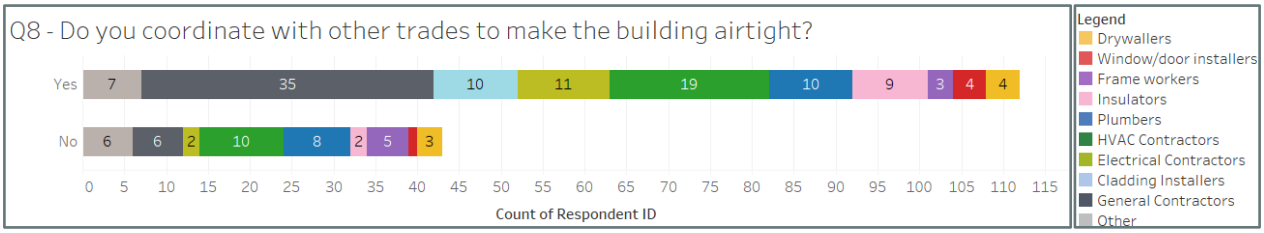


Figure 16 – Question 8 results - count of respondents for each answer and trade's breakdown.

Figure 16 shows the results of Question 8 with the breakdown of the trades who answered them. Details about the participants working in each trade can be found under Question 10. The chart shows that all of the cladding installers and the majority of general contractors, electrical contractors, insulators, window/door installers, and HVAC contractors coordinate with other trades. In addition, only 50-60% of drywallers, plumbers and other trades coordinate with others. Conversely, 5 out of 8 total frame workers mentioned that they do not coordinate with the rest to make the building airtight. This result is logical considering that the frame workers are the least interacting trade with the air barrier.

Question 9: Based on your "Yes" answer to Question 8, who do you coordinate with? (Select all that apply)

Answered: 110

Skipped: 114

Figure 17 shows the results of Question 9. The participants who coordinate with other trades indicated that they mostly work with general contractors. In addition, at least 50% of them also collaborate with cladding installers, insulators, window/door installers, frame workers, plumbers and HVAC contractors.

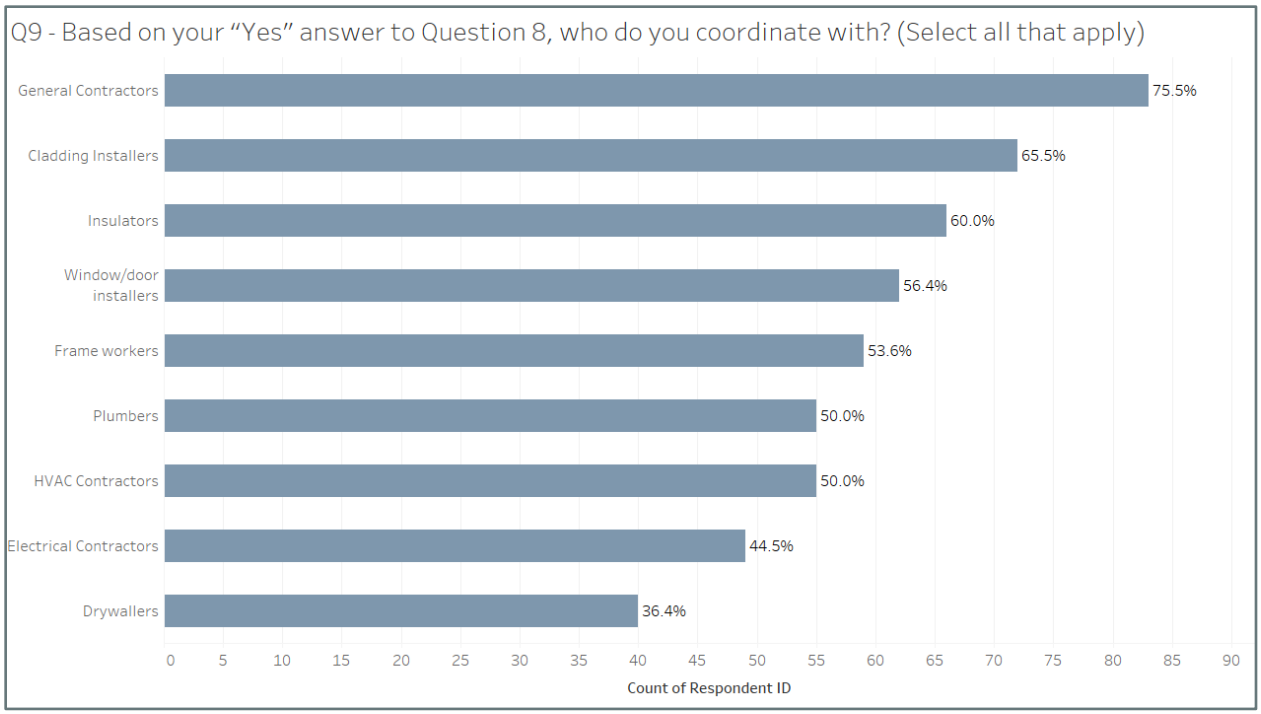


Figure 17 – Question 9 results - count of respondents for each answer.

Figure 18 shows the results of Question 9 with the breakdown of the trades who answered them. Details about the participants working in each trade can be found under Question 10. According to the number of people on the chart, general contractors mostly coordinate with cladding installers, insulators, and window/door installers. Cladding installers are coordinating with all the trades heavily except insulators and drywallers. Insulators themselves also collaborate with all the trades predominantly except only drywallers. In fact, drywallers are the one trade that all the others are least interoperating except electric contractors. This is presumably because drywallers usually join the construction at later stages. However, being responsible for finishing up the walls and ceilings put the drywallers in a position where they could have had more influence on air barrier installation and potential to coordinate with other trades than it appears to be.

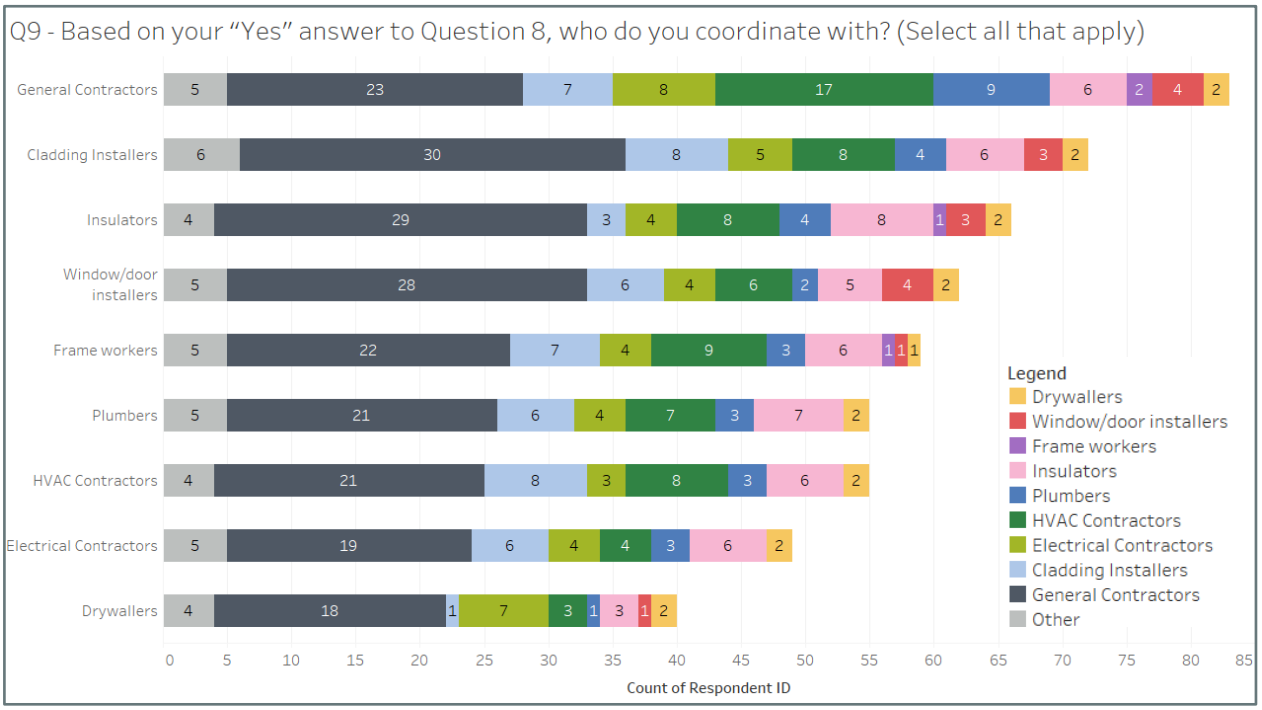


Figure 18 – Question 9 results - count of respondents for each answer and trade's breakdown.

Question 10: Which trade do you primarily work in?

Answered: 155

Skipped: 69

Figure 19 shows the results of Question 10. There are 41 answers for general contractors trade, 29 for HVAC contractors trade, 18 for plumbers trade, 13 for electrical contractors trade, 11 for insulators trade, 10 for cladding installers trade, 8 for frame workers trade, 7 for drywallers trade and 5 for window/door installers trade. In addition, 13 participants who are working for other trades include 1 concrete worker, 1 mason, 1 elevator worker, 1 finishing worker, 3 sprinkler installer, 3 building envelope supervisors, 1 site supervisor, 1 developer and 1 person who stated "all of the construction trades."

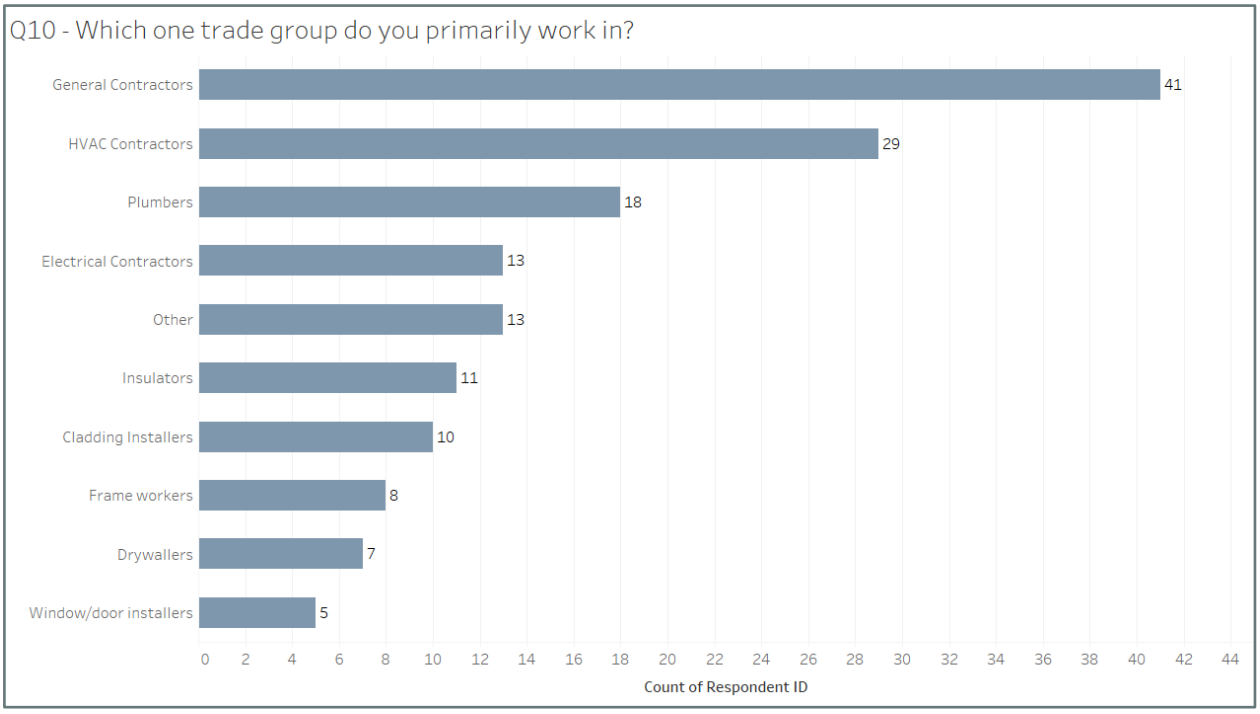


Figure 19 – Question 10 results - count of respondents for each answer.

Question 11.1: Based on your answer to question 10 (Drywallers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 5

Skipped: 2

Redirected: 217

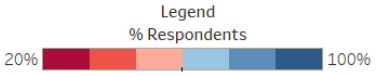
Figure 20 shows the results of Question 11.1. Only the participants who selected "Drywallers" in Question 10 received this set of questions in Figure 20 below about the details of the specific work they do on the construction site. According to the chart, the answers appear to be balanced except for 1 question. Reasonably, that is the question of installing a sheathing membrane and self-adhering membrane at the windows' and doors' sill/jamb/head transitions. Even though the number of participants who answered the question makes it difficult to draw solid conclusions, the results of Question11.1 show that drywallers are scarcely involved in the air barrier installation. Further research is suggested targeting the drywallers mainly because of their critical position on site by being able to note any deficiencies or penetrations in the air barrier before adding drywall.

The legend shown in Figure 20 is valid for the Question 11.1 to Question 11.9's results from Figure 20 to Figure 28.

Q11.1 - Drywallers, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
install a continuous air barrier that is lapped and sealed to the walls?	60% 3	40% 2
install a continuous air barrier that is lapped and sealed to the ceilings?	60% 3	40% 2
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	60% 3	40% 2
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	20% 1	80% 4
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	40% 2	60% 3
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	60% 3	40% 2
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	40% 2	60% 3
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	40% 2	60% 3

Figure 20 – Question 11.1 - Drywallers' results - count of respondents for each answer.



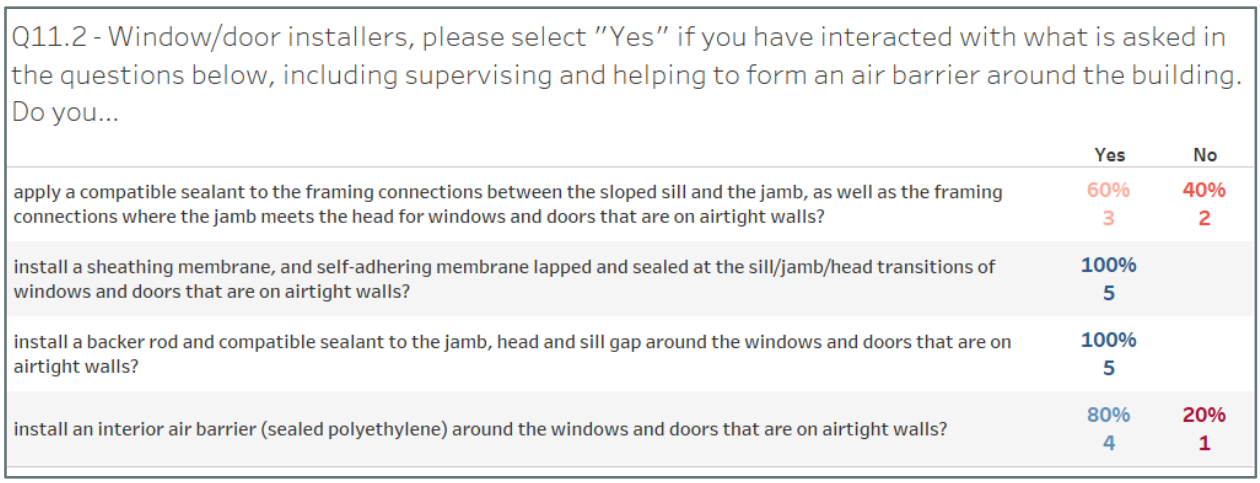
Question 11.2: Based on your answer to question 10 (Window/door installers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 5

Skipped: 0

Redirected: 219

Figure 21 shows the results of Question 11.2. Only the participants who selected "Window/door installers" in Question 10 received this set of questions in Figure 21 about the details of the specific work they do on the construction site. According to the chart, 100% of the window/door installers install the sheathing membrane at the fenestrations' sill/jamb/head transitions and apply sealants to the gaps around them. More than half of the window/door installers stated that they perform the installation works indicated in the other two questions, "applying a sealant to the framing connections" and "installing an air barrier around the fenestration after they are placed." Even though there are not enough answers to make a concrete conclusion, window and door installers give the impression that they do their part in installing the air barrier. Further studies are suggested targeting more participants working as window/door installers for more concrete results.



Q11.2 - Window/door installers, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	60% 3	40% 2
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	100% 5	
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	100% 5	
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	80% 4	20% 1

Figure 21 – Question 11.2 - Window/Door installers' results - count of respondents for each answer.

Question 11.3: Based on your answer to question 10 (Frame workers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 8

Skipped: 0

Redirected: 216

Figure 22 shows the results of Question 11.3. Only the participants who selected "Frame workers" in Question 10 received this set of questions in Figure 22 below about the details of the specific work they do on the construction site. Expectedly, more than 70% of the frame workers install the air barrier at the window frame transitions and around the exterior stairs, balconies, and decks' penetrations. Half of the frame workers also install the air barrier on the ceilings. The chart also shows that the rest of the work, including installing the air barrier to the walls, foundation-wall transitions, around the mechanical/ electrical/plumbing systems, roofs, and applying sealant around the metal flashings are mostly not performed by the framers. Additionally, the framers do not perform the works such as applying a sealant to the framing connections of the windows/doors and the jamb/head and sill gaps around the windows/doors and installing an air barrier around them after windows/doors are placed. Moreover, the chart shows that only 12.5% of the frame workers install the air barrier around the rim joists and apply a sealant around mechanical/electrical/plumbing systems on airtight assemblies.

The results of Question 11.3, in combination with the results of Question 8, show that frame workers are seldom involved in air barrier installation. This result is sensible considering that most of the frame building works are completed before the air barrier installations.

Q11.3 - Frame workers, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
install a continuous air barrier that is lapped and sealed to the walls?	37.5% 3	62.5% 5
install a continuous air barrier that is lapped and sealed to the ceilings?	50.0% 4	50.0% 4
install a continuous air barrier around the rim joists lapped and sealed?	12.5% 1	87.5% 7
apply a flexible sealant at the concrete foundation slab/wall transition?	37.5% 3	62.5% 5
apply a compatible sealant to the fillet joint between the foundation wall and the bottom wall plate?	25.0% 2	75.0% 6
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	37.5% 3	62.5% 5
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	71.4% 5	28.6% 2
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	25.0% 2	75.0% 6
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	37.5% 3	62.5% 5
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	12.5% 1	87.5% 7
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	25.0% 2	75.0% 6
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around exterior stairs, balconies, decks?	75.0% 6	25.0% 2
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around roofs?	37.5% 3	62.5% 5
apply a compatible sealant around the metal flashings that are on airtight walls?	37.5% 3	62.5% 5

Figure 22 – Question 11.3 - Frame workers' results - count of respondents for each answer.

Question 11.4: Based on your answer to question 10 (Insulators), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 10

Skipped: 1

Redirected: 213

Figure 23 shows the results of Question 11.4. Only the participants who selected "Insulators" in Question 10 received this set of questions in Figure 23 below about the details of the specific work they do on the construction site. According to at least 70% of the insulators, they install the interior air barrier to the walls, ceilings, rim joists, foundation and around windows/doors, mechanical/electrical/plumbing systems. More than half of the insulators stated that they install the exterior air barrier on stairs, balconies, decks and before the windows/doors are placed, then seal around the fenestration and the metal flashings. Lastly, only 30% of the insulators install the air barrier on the roofs. As a result, the insulators appear to be involved in almost all air barrier and sealant application stages except roofs.

Q11.4 - Insulators, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
install a continuous air barrier that is lapped and sealed to the walls?	80% 8	20% 2
install a continuous air barrier that is lapped and sealed to the ceilings?	80% 8	20% 2
install a continuous air barrier around the rim joists lapped and sealed?	70% 7	30% 3
apply a flexible sealant at the concrete foundation slab/wall transition?	70% 7	30% 3
apply a compatible sealant to the fillet joint between the foundation wall and the bottom wall plate?	60% 6	40% 4
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	50% 5	50% 5
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	50% 5	50% 5
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	60% 6	40% 4
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	90% 9	10% 1
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	90% 9	10% 1
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	90% 9	10% 1
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around exterior stairs, balconies, decks?	50% 5	50% 5
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around roofs?	30% 3	70% 7
apply a compatible sealant around the metal flashings that are on airtight walls?	50% 5	50% 5

Figure 23 – Question 11.4 - Insulators' results - count of respondents for each answer.

Question 11.5: Based on your answer to question 10 (Plumbers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 18

Skipped: 0

Redirected: 206

Figure 24 shows the results of Question 11.5. Only the participants who selected "Plumbers" in Question 10 received this set of questions in Figure 24 about the details of the specific work they do on the construction site. The answers to the plumber's questions are balanced. 50% to 60% of the plumbers confirm that they apply the sealants around the pipes then install the air barrier. Even though all the questions below are about plumbing works, 40-50% of the plumbers do not form the air barrier at any stage. This shows that plumbers might need improvement on their contribution to building the air barrier.

Q11.5 - Plumbers, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
apply a compatible sealant around the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?	61.1% 11	38.9% 7
cut a "+" or semi-circle through a gasket material less than the diameter of the pipe, then slide the gasket over the pipe to form an airtight seal for the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?	58.8% 10	41.2% 7
install any air barrier (sealed polyethylene, sheathing membrane) around the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?	52.9% 9	47.1% 8

Figure 24 – Question 11.5 - Plumbers' results - count of respondents for each answer.

Question 11.6: Based on your answer to question 10 (HVAC Contractors), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 27

Skipped: 2

Redirected: 195

Figure 25 shows the results of Question 11.6. Only the participants who selected "HVAC contractors" in Question 10 received this set of questions in Figure 25 about the details of the specific work they do on the construction site. Predictably, all of the HVAC contractors apply a sealant onto the mechanical ducts. Almost 80% of them use airtight mechanical boxes and apply a sealant around the HVAC equipment on airtight assemblies. Besides, half of them install the air barrier around the HVAC equipment after being placed and sealed. This shows that HVAC contractors might need attention on applying a sealant around the penetrations on airtight mechanical boxes and installing the air barrier around the HVAC equipment after being placed on airtight assemblies.

Q11.6 - HVAC Contractors, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
use airtight mechanical boxes for mechanical equipment (bathroom fans, exhaust fans) that is on airtight assemblies (wall, ceiling, roof, slab)?	77.8% 21	22.2% 6
apply a compatible sealant around the penetrations on airtight mechanical boxes?	53.8% 14	46.2% 12
apply a foil-faced tape or another joint sealer to mechanical ducts?	100.0% 27	
apply a compatible sealant around the HVAC equipment that is on airtight assemblies (wall, ceiling, roof, slab)?	80.8% 21	19.2% 5
install any air barrier (sealed polyethylene, sheathing membrane) around the HVAC equipment that is on airtight assemblies (wall, ceiling, roof, slab)?	53.8% 14	46.2% 12

Figure 25 – Question 11.6 - HVAC contractors' results - count of respondents for each answer.

Question 11.7: Based on your answer to question 10 (Electrical Contractors), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 13

Skipped: 0

Redirected: 211

Figure 26 shows the results of Question 11.7. Only the participants who selected "Electrical contractors" in Question 10 received this set of questions in Figure 26 about the details of the specific work they do on the construction site. According to the chart, all electrical contractors use airtight electrical boxes. In addition, more than half of them apply a compatible sealant to the penetrations on those airtight boxes, around electrical equipment that is on airtight assemblies, then install the air barrier themselves on their specific area of electrical works. Yet, they might need help improving the rate of applying sealants around the penetrations on airtight electrical boxes and electrical equipment on airtight assemblies.

Q11.7 - Electrical Contractors, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
use airtight electrical boxes for electrical equipment (recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?	100.0% 13	
apply a compatible sealant around the penetrations on airtight electrical boxes?	61.5% 8	38.5% 5
apply a compatible sealant around the electrical equipment that is on airtight assemblies (wall, ceiling, roof, slab)?	53.8% 7	46.2% 6
install any air barrier (sealed polyethylene, sheathing membrane) around the electrical equipment that is on airtight assemblies (wall, ceiling, roof, slab)?	69.2% 9	30.8% 4

Figure 26 – Question 11.7 - Electrical contractors' results - count of respondents for each answer.

Question 11.8: Based on your answer to question 10 (Cladding Installers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 8

Skipped: 2

Redirected: 214

Figure 27 shows the results of Question 11.8. Only the participants who selected "Cladding installers" in Question 10 received this set of questions in Figure 27 about the details of the specific work they do on the construction site. The chart shows that cladding installers assert that more than 70% of them install the air barrier to the walls, rim joists, roofs and around the windows, mechanical/electrical/plumbing systems, stairs, balconies, decks and apply sealants. Half of them note that they also apply a sealant to the framing connections of the windows/doors and the fillet joint between the foundation and the bottom plate of the wall. In addition, cladding installers mostly agree that they do not apply a sealant to the concrete foundation slab/wall transition. In conclusion, most cladding installers are highly engaged in air barrier installation and sealant application works except in foundations.

Q11.8 - Cladding Installers, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
install a continuous air barrier that is lapped and sealed to the walls?	87.5% 7	12.5% 1
install a continuous air barrier around the rim joists lapped and sealed?	75.0% 6	25.0% 2
apply a flexible sealant at the concrete foundation slab/wall transition?	37.5% 3	62.5% 5
apply a compatible sealant to the fillet joint between the foundation wall and the bottom wall plate?	50.0% 4	50.0% 4
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	50.0% 4	50.0% 4
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	75.0% 6	25.0% 2
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	62.5% 5	37.5% 3
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	71.4% 5	28.6% 2
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	87.5% 7	12.5% 1
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around exterior stairs, balconies, decks?	87.5% 7	12.5% 1
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around roofs?	71.4% 5	28.6% 2
apply a compatible sealant around the metal flashings that are on airtight walls?	71.4% 5	28.6% 2

Figure 27 – Question 11.8 - Cladding installers' results - count of respondents for each answer.

Question 11.9: Based on your answer to question 10 (General Contractors or Other), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Answered: 50

Skipped: 4

Redirected: 170

Q11.9 - General Contractors and other trades, please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. Do you...

	Yes	No
install a continuous air barrier that is lapped and sealed to the walls?	89.7% 35	10.3% 4
install a continuous air barrier that is lapped and sealed to the ceilings?	84.6% 33	15.4% 6
install a continuous air barrier around the rim joists lapped and sealed?	74.4% 29	25.6% 10
apply a flexible sealant at the concrete foundation slab/wall transition?	83.8% 31	16.2% 6
apply a compatible sealant to the fillet joint between the foundation wall and the bottom wall plate?	65.8% 25	34.2% 13
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	73.7% 28	26.3% 10
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	86.8% 33	13.2% 5
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	76.3% 29	23.7% 9
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	81.6% 31	18.4% 7
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	91.9% 34	8.1% 3
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	89.5% 34	10.5% 4
use airtight mechanical/electrical boxes for mechanical/electrical equipment (bathroom fans, exhaust fans, recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?	84.2% 32	15.8% 6
apply a compatible sealant around the penetrations on airtight mechanical/electrical boxes?	81.6% 31	18.4% 7
apply a foil-faced tape or another joint sealer to mechanical ducts?	86.8% 33	13.2% 5
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around exterior stairs, balconies, decks?	68.4% 26	31.6% 12
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around roofs?	55.3% 21	44.7% 17
apply a compatible sealant around the metal flashings that are on airtight walls?	68.4% 26	31.6% 12

Figure 28 – Question 11.9 - General contractors' results - count of respondents for each answer.

Figure 28 shows the results of Question 11.9 for general contractors solely. Only the participants who selected "General contractors" and "Other" in Question 10 received this set of questions in Figure 28 about the details of the specific work they do on the construction site. The chart shows that more than 55% of the general contractors install and seal the air barrier in all the details asked. 55% to 70% of them install it to the roofs, exterior stairs, balconies decks and apply a sealant around the metal flashings. Further, at least 70% of them install it to the walls, ceilings, rim joists, and around windows, doors, mechanical/ electrical/plumbing systems. The results of Question 11.9 demonstrate that the general contractors are involved in every possible stage of installing the air barrier and applying a sealant.

Question 12: If you have answered "Yes" to any one of the previous questions, what is the most common material you use to form a continuous air barrier, including air-impermeable materials and sealants? (Select all that apply)

Answered: 134

Skipped: 90

Figure 29 shows the results of Question 12. According to the chart, 50% of the total participants use polyethylene sheet as an air barrier layer, 30% use sheathing membrane, and 20% use other materials such as drywall, spray foam, and different membranes. In the “Other” section, many mentioned sealants and tapes as well. Lastly, 12% of them stated that they do not know the materials they use. This chart also reflects the most common industry practice of the air barrier and is a considerable opportunity to improve the knowledge of exterior air barrier systems.

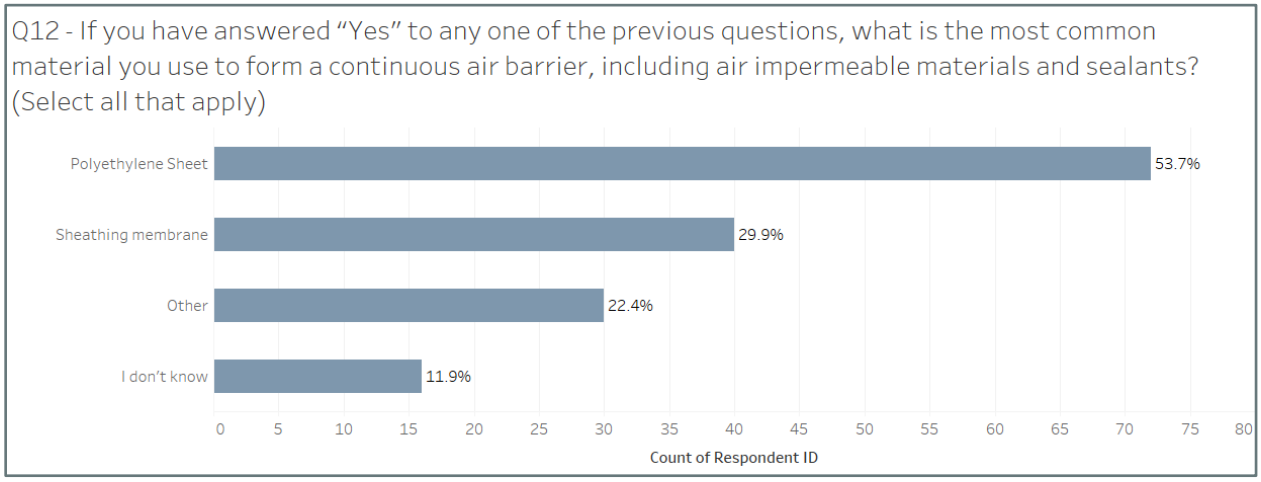


Figure 29 – Question 12 results - count of respondents for each answer.

3.3 Demographics Questions

General analysis of the participants are listed here, such as how many people joined from each district and what kind of projects they work on.

Question 13: Which regions do you primarily work in? (Select all that apply)

Answered: 135

Skipped: 89

Figure 30 shows the results of Question 13. The chart shows that more than 90% of the participants who joined the survey primarily work in the lower mainland of BC.

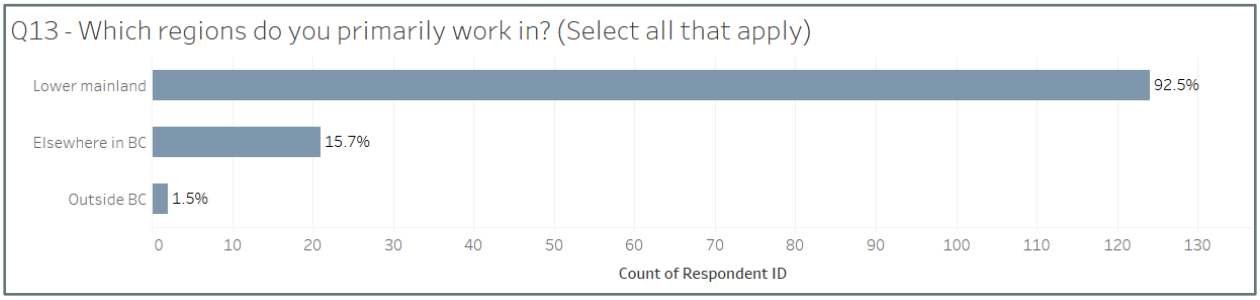


Figure 30 – Question 13 results - count of respondents for each answer.

Question 14: What types of projects do you work on? (Select all that apply)

Answered: 136

Skipped: 88

Figure 31 shows the results of Question 14. According to the chart, most of the participants work in single-family dwellings. The other options, rowhouses/townhouses, residential alterations/renovations, apartments and non-residential buildings have a 40-50% ratio of the participants who work on them. Besides, based on the post-survey analysis, there are only 7 people who solely work on non-residential buildings. This means only 5% of the participants who answered this question do not have work experience in residential buildings.

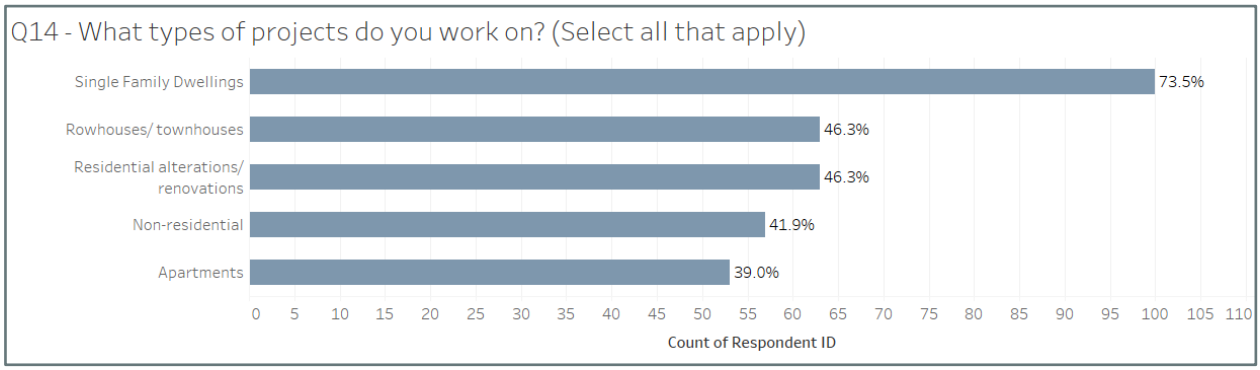


Figure 31 – Question 14 results - count of respondents for each answer.

4. Conclusion and Next Steps

This report compiles information gathered through an online survey conducted between June 21st - July 5th, 2021, for the purpose of understanding the building trades' knowledge and experience about airtightness barriers to enhance the quality of Part 3 and Part 9 buildings' construction. The survey's main objective was to understand the gaps in knowledge and share of responsibilities about implementing air barriers to meet BC Energy Step Code requirements at the point of on-site application. Airtight envelopes are a critical aspect of construction because of their significant impact on reducing energy consumption, GHG emissions, and maintenance expenses. Moreover, with the adoption of Upper Steps in the Step Code, airtightness requirements will only increase. In this context, the survey aimed to identify the parties of most significance in building construction to better understand the phenomenon of air tightness for its theoretical and practical aspects. The survey posed 14 questions regarding the air barrier installation materials and procedures in constructing Part 9 and Part 3 wood-frame multi-unit residential buildings. The questions were addressed to different construction trades' workers and supervisors placed under three main categories.

To restate, the numbers of participants with their associated trades are:

- Drywaller: 7
- Window/Door Installers: 5
- Frame Workers: 8
- Insulators: 11
- Plumbers: 18
- HVAC Contractors: 29
- Electrical Contractors: 18
- Cladding Installers: 10
- General Contractors: 41
- Other: 13

4.1 Conclusions

Conclusions were curated in line with the inferences made within each category of the survey questions.

General knowledge:

- Trades should be trained on the air barrier's requirements so that the barrier will last through the building's lifespan. Less than half of the participants know that the air barrier must be durable, strong and stiff.
- Another area of improvement is the participants' awareness of different materials and sealants that can be used as air barriers, such as drywall, sheet metal, closed-cell foam tape and foam backer rod. An expanded range of material options could increase the rate of passing the door blower test with the materials within their reach on site.

- The trades are primarily familiar with the sealed polyethylene air barrier approach. However, they are only moderately familiar with other methods such as airtight drywall, mechanically fastened sheathing and liquid applied sheathing.

Responsibilities on site:

- More than half of all the participants agree that the installation of the air barrier is performed by cladding installers and insulators. This does not necessarily suggest that the survey participants place the responsibility of air barrier installation on the work scope of cladding installers and insulators. The 3rd ranking trade is the general contractors, with 33% of total participants' indication.
- On the contrary to the previous point, 80% of the participants stated that general contractors should be in charge of the air barrier, including general contractors themselves. This might be considered a valid statement because the number of general contractors is the highest number among the survey participants.
- According to the construction trades' workers or supervisors who joined the survey:
    - air barriers at foundations are installed by 60-70% of insulators and 66-84% of general contractors.
    - air barriers at floors are evaluated in two separate groups. First, at rim joists, they are installed by 70% of insulators, 74% of general contractors and 75% of cladding installers. Second, at exterior stairs', balconies,' decks' penetrations air barriers are installed by 68% of general contractors, 75% of frame workers and 88% of cladding installers.
    - air barriers at walls are installed by 80% of insulators, 88% of cladding installers. 90% of general contractors.
    - air barriers at ceilings are installed by 60% of drywallers, 80% of insulators and 85% of general contractors.
    - air barriers at roofs are installed by 55% of general contractors and 71% of cladding installers.
    - air barriers at windows/doors are installed in a few steps. Installing the air barrier before the windows and doors are placed and applying a sealant after are performed by 75-63% of cladding installers, 87-76% of general contractors and 100% of window/door installers. Installation of the air barrier after the windows and doors are placed is performed by 80% of window/door installers, 82% of general contractors and 90% of insulators.
    - air barriers at mechanical/electrical/plumbing penetrations are completed mainly in two steps. Firstly, applying a sealant after the mechanical equipment is performed by 71% of cladding installers, 90% of insulators and 92% of general contractors. Secondly, installing the air barrier is performed by 88% of cladding installers, 89% of general contractors and 90% of insulators. In addition, for mechanical penetrations, the air barrier is installed by 81% of HVAC contractors and sealed by 54% of them. For electrical penetrations, the air barrier is installed by 54% of electrical contractors and sealed by 69% of them. Lastly, for plumbing penetrations, the air barrier is installed by 60% of plumbers and sealed by 53% of them.

The list above shows only the percent of the trades that agreed with more than 50% ratio and/or ranked top 3 for the specified group of work. The full list of all works with all trades' "Yes" answers can be found in Figure 32.

- Interestingly, most window/door installers, insulators, cladding installers and general contractors noted responsibility for the air barrier installation on site. In addition, plumbers, HVAC contractors, and electrical contractors mainly claimed responsibility for the sealant application around their equipment but not the air barrier installation. One explanation for this difference in responsibilities could be that the definition of duties of the air barrier installation works is still relatively vague. This structure could result from the gradual progression of traditional constructional operations built over time. Yet, the construction industry can focus its efforts on redefining the responsibilities on site for improved outcomes clearly. Another option would be to give that responsibility to a specialized group of people on air barriers to build the air barrier layer on the construction site just like any other construction trade specialized on specific works.

Demographics:

- Participants who joined the survey mostly work in the lower mainland. With the expanding scope of the future studies' targets, the number of participants from other parts of BC might also be increased. Considering the fact that air barrier application is particularly highlighted in the Upper Steps codes, it is likely that the construction trades working in the lower mainland are more familiar with it. This might explain why the construction trades who joined the survey show an eager attitude towards taking more responsibility for building airtight buildings. Hence, it is for this reason that the survey should be expanded so as to reach more realistic results.
- 95% of the participants have experience working in residential buildings. It is possible to claim that the high rate of acquaintance with the air barrier may result from this experience on different types of residential buildings.

4.2 Next Steps

Another survey should be conducted with more participants to determine which construction trade needs improvement and training about airtightness in their work line. Therefore, there are two significant actions that the Township of Langley is recommended to take. They can be listed as research-oriented and education-oriented actions.

Research:

- The number of participants joined from drywallers (7), window/door installers (5), frame workers (8), cladding installers (10), insulators (11) are particularly low. Therefore, there the following survey and research should focus on those trades for more substantial results.

- In addition to the previous point, broadening the number of survey participants for all trades would increase the accuracy of the results. Thus, for further studies, more participants should be aimed.

Education:

- All the construction trades can be educated on the importance of the air barrier to make buildings greener.
- Based on the answers to the general questions, the trades might be educated on various materials and sealants of air barriers to increasing the rate of passing the door blower test.
- In addition, the trades could also be trained on different air barrier methods such as airtight drywall, mechanically fastened sheathing and liquid applied sheathing approaches. The most common industry practice is the use of polyethylene for the air barrier. This leaves a great opportunity to extend the use of the exterior air barrier methods, which might be more efficient depending on the projects' circumstances.
- Based on their answers to the technical questions, drywallers, plumbers, HVAC contractors, electrical contractors should be paid special attention. They could be trained on air barrier installation and sealant application. The frame workers also seem to be rarely involved in air barrier works; however, since they are mostly joining the construction works prior to installing the air barrier, they could be omitted.

	Drywallers	Window/door installers	Frame workers	Insulators	Plumbers	HVAC Contractors	Electrical Contractors	Cladding Installers	General Contractors	Other
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
apply a flexible sealant at the concrete foundation slab/wall transition?			38%	70%				38%	84%	36%
apply a compatible sealant to the fillet joint between the foundation wall and the bottom wall plate?			25%	60%				50%	66%	27%
install a continuous air barrier around the rim joists lapped and sealed?			13%	70%				75%	74%	60%
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around exterior stairs, balconies, decks?			75%	50%				88%	68%	50%
install a continuous air barrier that is lapped and sealed to the walls?	60%		38%	80%				88%	90%	55%
install a continuous air barrier that is lapped and sealed to the ceilings?	60%		50%	80%					85%	50%
install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around roofs?			38%	30%				71%	55%	40%
apply a compatible sealant to the framing connections between the sloped sill and the jamb, as well as the framing connections where the jamb meets the head for windows and doors that are on airtight walls?	60%	60%	38%	50%				50%	74%	55%
install a sheathing membrane, and self-adhering membrane lapped and sealed at the sill/jamb/head transitions of windows and doors that are on airtight walls?	20%	100%	71%	50%				75%	87%	45%
install a backer rod and compatible sealant to the jamb, head and sill gap around the windows and doors that are on airtight walls?	40%	100%	25%	60%				63%	76%	60%
install an interior air barrier (sealed polyethylene) around the windows and doors that are on airtight walls?	60%	80%	38%	90%					82%	45%
apply a compatible sealant around mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	40%		13%	90%				71%	92%	55%
install any air barrier (sealed polyethylene, sheathing membrane) around the mechanical/electrical/plumbing systems that are on airtight assemblies (wall, ceiling, roof, slab)?	40%		25%	90%				88%	89%	55%
use airtight mechanical/electrical boxes for mechanical/electrical equipment (bathroom fans, exhaust fans, recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?									84%	64%
apply a compatible sealant around the penetrations on airtight mechanical/electrical boxes?									82%	70%
use airtight mechanical boxes for mechanical equipment (bathroom fans, exhaust fans) that is on airtight assemblies (wall, ceiling, roof, slab)?						78%				
apply a compatible sealant around the penetrations on airtight mechanical boxes?						54%				
apply a foil-faced tape or another joint sealer to mechanical ducts?						100%			87%	80%
apply a compatible sealant around the HVAC equipment that is on airtight assemblies (wall, ceiling, roof, slab)?						81%				
install any air barrier (sealed polyethylene, sheathing membrane) around the HVAC equipment that is on airtight assemblies (wall, ceiling, roof, slab)?						54%				
use airtight electrical boxes for electrical equipment (recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?							100%			
apply a compatible sealant around the penetrations on airtight electrical boxes?							62%			
apply a compatible sealant around the electrical equipment that is on airtight assemblies (wall, ceiling, roof, slab)?							54%			
install any air barrier (sealed polyethylene, sheathing membrane) around the electrical equipment that is on airtight assemblies (wall, ceiling, roof, slab)?							69%			
apply a compatible sealant around the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?					61%					
cut a "+" or semi-circle through a gasket material less than the diameter of the pipe, then slide the gasket over the pipe to form an airtight seal for the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?					59%					
install any air barrier (sealed polyethylene, sheathing membrane) around the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?					53%					
apply a compatible sealant around the metal flashings that are on airtight walls?			38%	50%				71%	68%	40%

Figure 32 – Master list of trades' questions asked to all trades as part of Q11s.

5. References

BC Housing. (2018). *BC Energy Step Code: Builder Guide*. Retrieved from https://www.bchousing.org/research-centre/library/residential-design-construction/bc-energy-step-code-builder-guide&sortType=sortByDate

BC Housing. (2020). *Building Enclosure Design Guide: Wood-Frame Multi-Unit Residential Buildings* (2nd ed.). Retrieved from https://www.bchousing.org/research-centre/library/residential-design-construction/building-enclosure-design-guide

BC Housing. (2020). *Building Envelope Guide for Houses: Part 9 - Residential Construction* (2nd ed.). Retrieved from https://www.bchousing.org/research-centre/library/residential-design-construction/building-envelope-guide-part-9

6. Abbreviations

Abbreviation	Full Name	Explanation
ACH	Air changes per hour	The measure of the air volume added to or removed from a space in one hour
BC	British Columbia	Refers to the Province of British Columbia.
BC ESC	British Columbia Energy Step Code	Provincial regulation supporting energy efficiency for various building types.
BCBC	British Columbia Building Code	Provincial regulation on how new construction, building alterations, repairs and demolitions are done. This code sets minimum requirements for safety, health, accessibility, fire and structural protection of buildings and energy and water efficiency.
MURB	Multi-Unit Residential Buildings	A building comprised of a common entrance and separate units that are also known as apartments constructed for dwelling purposes.
VBBL	Vancouver Building By-Law	The City of Vancouver's by-law that regulates the design and construction of buildings, as well as the administrative provisions related to permitting, inspections, and the enforcement of these requirements.

7. Appendices

The appendices for this Project can be found in the subsequent pages.

Appendix A Survey Questions

BCBC Airtightness Compliance - Air Barrier Best Practices Survey

The Township of Langley needs your help to support the building industry meet BC Energy Step Code/BCBC airtightness targets, more predictably, with fewer challenges, and with fewer resources.

The Green Buildings Team at the Township of Langley, in partnership with the UBC Sustainability Scholar Program, is working on a report to support industry in meeting provincial and municipal energy related compliance targets: "Making our buildings greener: which building industries need support in the successful implementation of high-performance residential building envelopes?"

This is an invitation to help collectively enhance the construction practice of a variety of stakeholders in the Part 9 construction industry. The results of this Project will be made available to all industries across BC and intend to help reduce the challenges with meeting increasingly challenging airtightness targets. We are collecting data through an online survey, taking no more than 15 minutes to complete; this data will help us understand where construction practices can improve to make it easier to reach Step Code airtightness targets.

This survey is not a test or a judge of professional practice – no answer is incorrect. It is important to be as honest as possible in your answers – if you don't know the answer to a question, choose "I don't know." If you find yourself choosing "I don't know" often, that's still very helpful information! No personal information will be shared. If you require help to answer some questions, click the link in that question to see pictures.

Definitions:

Airtightness is the resistance to inward or outward air leakage through unintentional leakage points or areas in the building envelope. This air leakage is driven by differential pressures across the building envelope due to the combined effects of stack, external wind, and mechanical ventilation systems.

Air Barrier refers to materials and components that, together, control the flow of air through an assembly and thus limit the potential for heat loss and condensation due to air movement.

Thank you for participating in this survey. Click NEXT to continue into the survey.

Question 1: In your opinion, how important is the airtightness of a building on average in your everyday work?

Options to Q1: *5 points Likert Scale*

Very Important	Somewhat Important	Neutral	Somewhat Unimportant	Very Unimportant

Please explain your answer.

Note: The next four questions will give us an idea of your current knowledge of air barriers

Question 2: Which of the following are requirements of a building's air barrier? (Select all that apply)

Options to Q2:

Air impermeability
Continuity of air barrier
Durability
Strength & Stiffness
I don't know

Question 3: Which building materials can be considered airtight? (Select all that apply)

Options to Q3:

Concrete
Drywall
Plywood
Spray foam insulation
Rigid insulation
Polyethylene sheet
Sheet metal
Breathable sheathing membrane
Liquid applied membrane
I don't know

Question 4: Which of these sealants can be used to seal the air barrier? (Select all that apply)

Options to Q4:

Acoustic sealant
EPDM neoprene rubber
Closed cell foam backer rod
Closed cell foam tape
Butyl sealant
Silicone caulk
Polyurethane
Sheathing tape
I don't know

Question 5: How familiar are you with the following interior and exterior airtightness approaches?

Options to Q5: *5 points Likert Scale*

	Extremely	Very	Moderately	Slightly	Not at all
Sealed polyethylene approach (interior)					
Airtight drywall approach (interior)					

Mechanically fastened sheathing membrane approach (exterior)					
Self-adhered sheathing membrane approach (exterior)					
Liquid applied sheathing membrane approach (exterior)					
Sealed sheathing approach (exterior)					
Other (Please specify)					

Question 6: To your knowledge, who wraps the polyethylene sheet or sheathing membrane as an air barrier around the building? (Select all that apply)

Options to Q6:

Drywallers
Window/door installers
Frame workers
Insulators
Plumbers
HVAC Contractors
Electrical Contractors
Cladding Installers
General Contractors
Other (Please specify)
I don't know

Question 7: To your knowledge, who is/should be in charge of air barrier quality control on a construction site? (Select all that apply)

Options to Q7:

Drywallers
Window/door installers
Frame workers
Insulators
Plumbers
HVAC Contractors
Electrical Contractors
Cladding Installers
General Contractors
Other (Please specify)
I don't know

Question 8: Do you coordinate with other trades to make the building airtight?

Options to Q8:

Yes
No

Question 9 if "Yes**" to Question 8:** Based on your "Yes" answer to Question 8, who do you coordinate with? (Select all that apply)

Options to Q9:

Drywallers
Window/door installers
Frame workers
Insulators
Plumbers
HVAC Contractors
Electrical Contractors
Cladding Installers
General Contractors
Other (Please specify)

Question 10: Which trade do you primarily work in?

Options to Q10:

Drywallers
Window/door installers
Frame workers
Insulators
Plumbers
HVAC Contractors
Electrical Contractors
Cladding Installers
General Contractors
Other (Please specify)

Question 11.1 if "Drywallers**" to question 10:** Based on your answer to question 10 (Drywallers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.1: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
1	install a continuous air barrier that is lapped and sealed to the **walls**?		
2	install a continuous air barrier that is lapped and sealed to the **ceilings**?		
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		

7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
9	install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?		
14	apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
13	install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		

Question 11.2 if "Window/door installers**" to question 10:** Based on your answer to question 10 (Window/door installers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.2: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		
7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
9	install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?		

Question 11.3 if "Frame workers**" to question 10:** Based on your answer to question 10 (Frame workers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.3: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
1	install a continuous air barrier that is lapped and sealed to the **walls**?		
2	install a continuous air barrier that is lapped and sealed to the **ceilings**?		
3	install a continuous air barrier around the **rim joists** lapped and sealed?		
4	apply a flexible sealant at the concrete foundation **slab/wall transition**?		
5	apply a compatible sealant to the **fillet joint** between the foundation wall and the bottom wall plate?		
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		

7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
9	install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?		
14	apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
13	install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
26	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **exterior stairs, balconies, decks**?		
27	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **roofs**?		
28	apply a compatible sealant around the **metal flashings** that are on airtight walls?		

Question 11.4 if "Insulators**" to question 10:** Based on your answer to question 10 (Insulators), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.4: *2 points Likert Scale – Note: "Insulators" questions are identical with "Frame workers" questions. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
1	install a continuous air barrier that is lapped and sealed to the **walls**?		
2	install a continuous air barrier that is lapped and sealed to the **ceilings**?		
3	install a continuous air barrier around the **rim joists** lapped and sealed?		
4	apply a flexible sealant at the concrete foundation **slab/wall transition**?		
5	apply a compatible sealant to the **fillet joint** between the foundation wall and the bottom wall plate?		
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		
7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
9	install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?		
14	apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
13	install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
26	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **exterior stairs, balconies, decks**?		

27	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **roofs**?		
28	apply a compatible sealant around the **metal flashings** that are on airtight walls?		

Question 11.5 if "Plumbers**" to question 10:** Based on your answer to question 10 (Plumbers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.5: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
10	apply a compatible sealant around the **pipes** that are on airtight assemblies (wall, ceiling, roof, slab)?		
11	cut a "+" or semi-circle through a gasket material less than the diameter of the pipe, then slide the **gasket over the pipe** to form an airtight seal for the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?		
12	install any air barrier (sealed polyethylene, sheathing membrane) around the **pipes** that are on airtight assemblies (wall, ceiling, roof, slab)?		

Question 11.6 if "HVAC Contractors**" to question 10:** Based on your answer to question 10 (HVAC Contractors), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.6: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
17	use **airtight mechanical boxes** for mechanical equipment (bathroom fans, exhaust fans) that is on airtight assemblies (wall, ceiling, roof, slab)?		
18	apply a compatible sealant around the **penetrations on airtight mechanical boxes**?		
19	apply a foil-faced tape or another joint sealer to **mechanical ducts**?		
20	apply a compatible sealant around the **HVAC equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?		
21	install any air barrier (sealed polyethylene, sheathing membrane) around the **HVAC equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?		

Question 11.7 if "Electrical Contractors**" to question 10:** Based on your answer to question 10 (Electrical Contractors), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.7: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
22	use **airtight electrical boxes** for electrical equipment (recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?		
23	apply a compatible sealant around the **penetrations on airtight electrical boxes**?		
24	apply a compatible sealant around the **electrical equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?		
25	install any air barrier (sealed polyethylene, sheathing membrane) around the **electrical equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?		

Question 11.8 if "Cladding Installers**" to question 10:** Based on your answer to question 10 (Cladding Installers), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.8: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
1	install a continuous air barrier that is lapped and sealed to the **walls**?		
3	install a continuous air barrier around the **rim joists** lapped and sealed?		
4	apply a flexible sealant at the concrete foundation **slab/wall transition**?		
5	apply a compatible sealant to the **fillet joint** between the foundation wall and the bottom wall plate?		
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		
7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
14	apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
13	install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
26	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **exterior stairs, balconies, decks**?		
27	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **roofs**?		
28	apply a compatible sealant around the **metal flashings** that are on airtight walls?		

Question 11.9 if "General Contractors**" or "**Other**" to question 10:** Based on your answer to question 10 (General Contractors or Other), please select "Yes" if you have interacted with what is asked in the questions below, including supervising and helping to form an air barrier around the building. (If you require help to answer this question, view these pictures). Do you…

Options to Q11.9: *2 points Likert Scale. The Q# on the first column in the table below is a reference to the master list of trades questions in Appendix B.*

Q#		Yes	No
1	install a continuous air barrier that is lapped and sealed to the **walls**?		
2	install a continuous air barrier that is lapped and sealed to the **ceilings**?		
3	install a continuous air barrier around the **rim joists** lapped and sealed?		
4	apply a flexible sealant at the concrete foundation **slab/wall transition**?		
5	apply a compatible sealant to the **fillet joint** between the foundation wall and the bottom wall plate?		
6	apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?		
7	install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?		
8	install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?		
9	install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?		
14	apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
13	install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?		
15	use **airtight mechanical/electrical boxes** for mechanical/electrical equipment (bathroom fans, exhaust fans, recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?		
16	apply a compatible sealant around the **penetrations on airtight mechanical/electrical boxes**?		
19	apply a foil-faced tape or another joint sealer to **mechanical ducts**?		
26	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **exterior stairs, balconies, decks**?		
27	install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **roofs**?		
28	apply a compatible sealant around the **metal flashings** that are on airtight walls?		

Question 12: If you have answered "Yes" to any one of the previous questions, what is the most common material you use to form a continuous air barrier, including air impermeable materials and sealants? (Select all that apply)

Options to Q12:

Polyethylene Sheet
Sheathing membrane
Other (Please specify)
I don't know

Question 13: Which regions do you primarily work in? (Select all that apply)

Options to Q13:

Lower mainland
Elsewhere in BC

Outside BC

Question 14: What types of projects do you work on? (Select all that apply)

Options to Q14:

Single Family Dwellings
Rowhouses/ townhouses
Apartments
Residential alterations/ renovations
Non-residential
Other (Please specify)

Appendix B Master List of Trades' Questions

Do you…

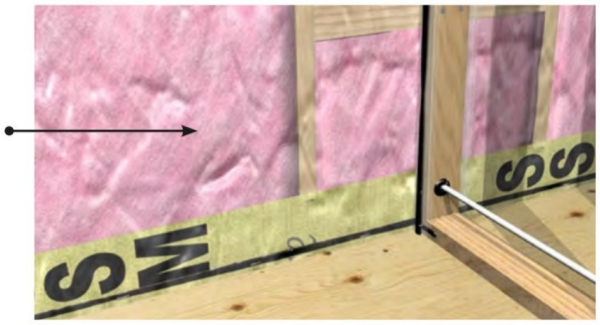
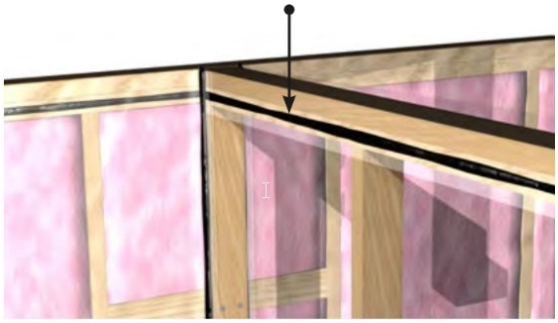
1. install a continuous air barrier that is lapped and sealed to the **walls**?
2. install a continuous air barrier that is lapped and sealed to the **ceilings**?
3. install a continuous air barrier around the **rim joists** lapped and sealed?
4. apply a flexible sealant at the concrete foundation **slab/wall transition**?
5. apply a compatible sealant to the **fillet joint** between the foundation wall and the bottom wall plate?
6. apply a compatible sealant to the **framing connections** between the sloped sill and the jamb, as well as the **framing connections** where the jamb meets the head for windows and doors that are on airtight walls?
7. install a sheathing membrane, and self-adhering membrane lapped and sealed at the **sill/jamb/head transitions of windows and doors** that are on airtight walls?
8. install a backer rod and compatible sealant to the **jamb, head and sill gap around the windows and doors** that are on airtight walls?
9. install an interior air barrier (sealed polyethylene) around the **windows and doors** that are on airtight walls?
10. apply a compatible sealant around the **pipes** that are on airtight assemblies (wall, ceiling, roof, slab)?
11. cut a "+" or semi-circle through a gasket material less than the diameter of the pipe, then slide the **gasket over the pipe** to form an airtight seal for the pipes that are on airtight assemblies (wall, ceiling, roof, slab)?
12. install any air barrier (sealed polyethylene, sheathing membrane) around the **pipes** that are on airtight assemblies (wall, ceiling, roof, slab)?
13. install any air barrier (sealed polyethylene, sheathing membrane) around the **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?
14. apply a compatible sealant around **mechanical/electrical/plumbing systems** that are on airtight assemblies (wall, ceiling, roof, slab)?
15. use **airtight mechanical/electrical boxes** for mechanical/electrical equipment (bathroom fans, exhaust fans, recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?
16. apply a compatible sealant around the **penetrations on airtight mechanical/electrical boxes**?
17. use **airtight mechanical boxes** for mechanical equipment (bathroom fans, exhaust fans) that is on airtight assemblies (wall, ceiling, roof, slab)?
18. apply a compatible sealant around the **penetrations on airtight mechanical boxes**?
19. apply a foil-faced tape or another joint sealer to **mechanical ducts**?
20. apply a compatible sealant around the **HVAC equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?
21. install any air barrier (sealed polyethylene, sheathing membrane) around the **HVAC equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?

22. use **airtight electrical boxes** for electrical equipment (recessed lights, plugs) that is on airtight assemblies (wall, ceiling, roof, slab)?
23. apply a compatible sealant around the **penetrations on airtight electrical boxes**?
24. apply a compatible sealant around the **electrical equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?
25. install any air barrier (sealed polyethylene, sheathing membrane) around the **electrical equipment** that is on airtight assemblies (wall, ceiling, roof, slab)?
26. install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **exterior stairs, balconies, decks**?
27. install any air barrier (sheathing membrane, self-adhering membrane) lapped and sealed around **roofs**?
28. apply a compatible sealant around the **metal flashings** that are on airtight walls?

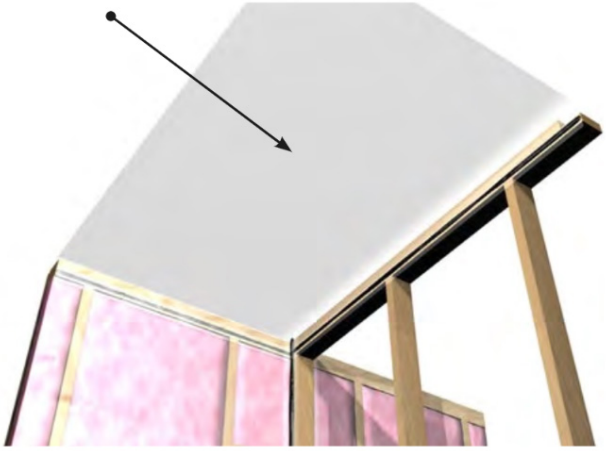
Appendix C Explanatory Figures for the Trades' Questions

Below are selected figures to explain what is asked in each survey question. The figures are derived from Building Envelope Guide for Houses: Part 9 - Residential Construction, Second Edition (BC Housing, 2020) and Building Enclosure Design Guide: Wood-Frame Multi-Unit Residential Buildings, Second Edition (2020). Separate documents are created and added to the survey as an external link with different set of figures to guide each trades' questions. The question numbers follow the master list of trades questions in Appendix B.

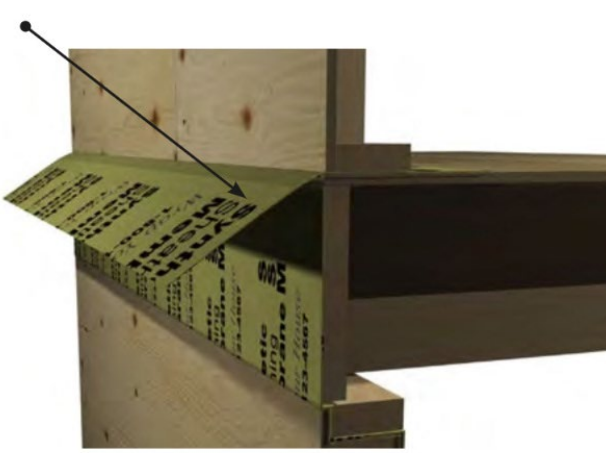
1. Examples of sealed polyethylene installation to the **walls**

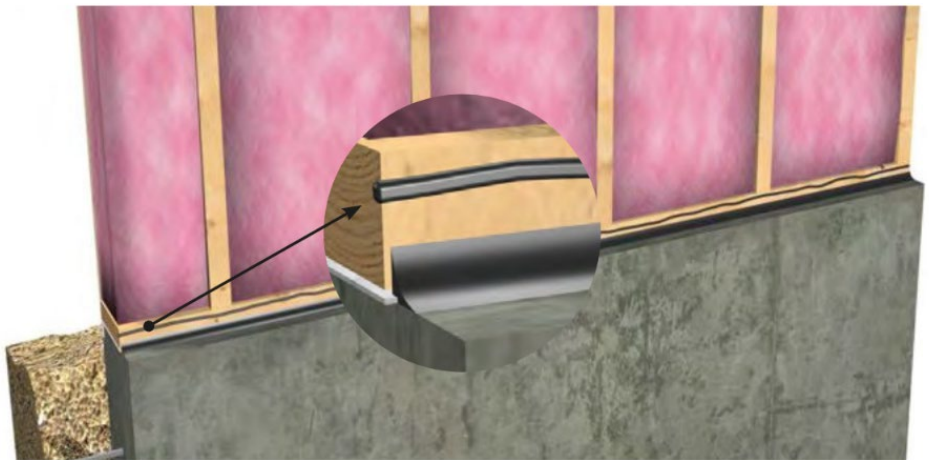
2. Examples of sealed polyethylene installation to the **ceilings**




3. Examples of synthetic sheathing membrane installation and sealant application around the **rim joists**

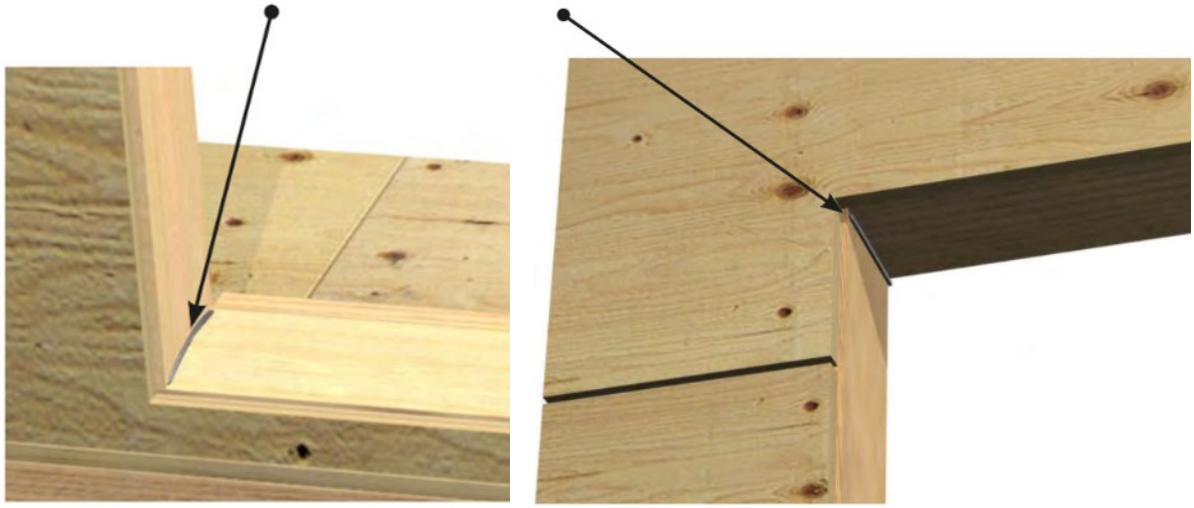


4. Example of sealing concrete foundation **slab/wall transition**

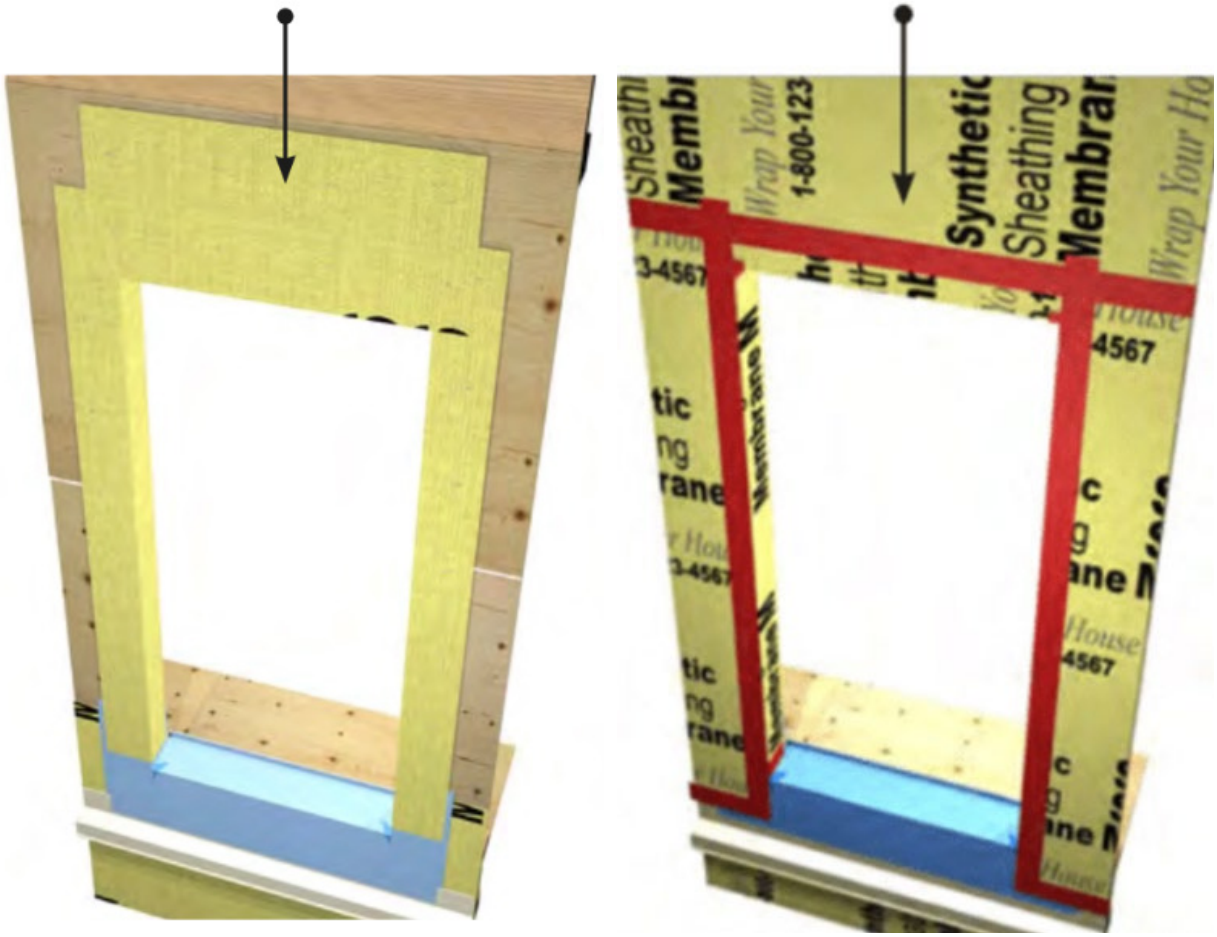


5. Example of sealant application to the **fillet joint** between the foundation wall and the bottom wall plate

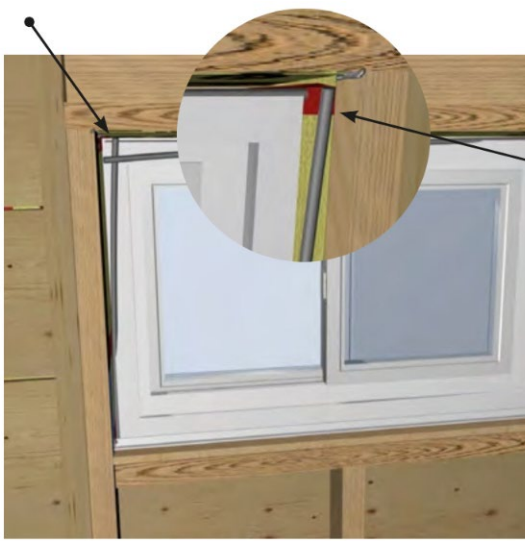
6. Examples of sealing **framing connections of windows and doors**

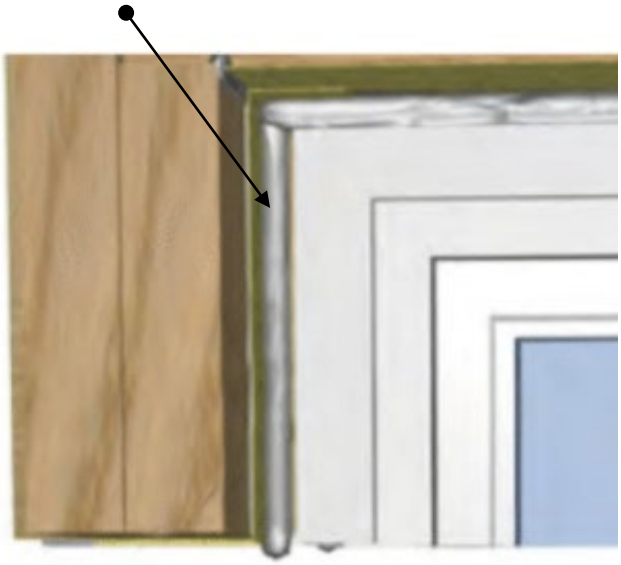


7. Examples of synthetic sheathing membrane installation and sealant application at the **sill/jamb/head transitions of windows and doors**

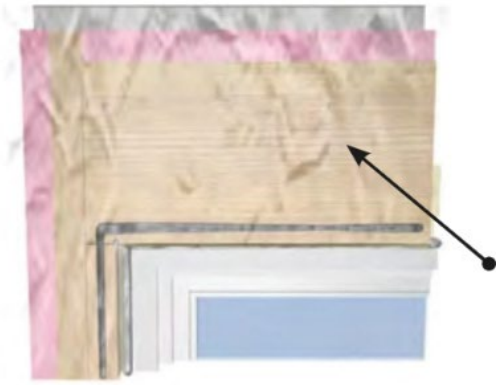


8. Examples of backer rod installation and sealant application to the **jamb, head and sill gap around the windows and doors**

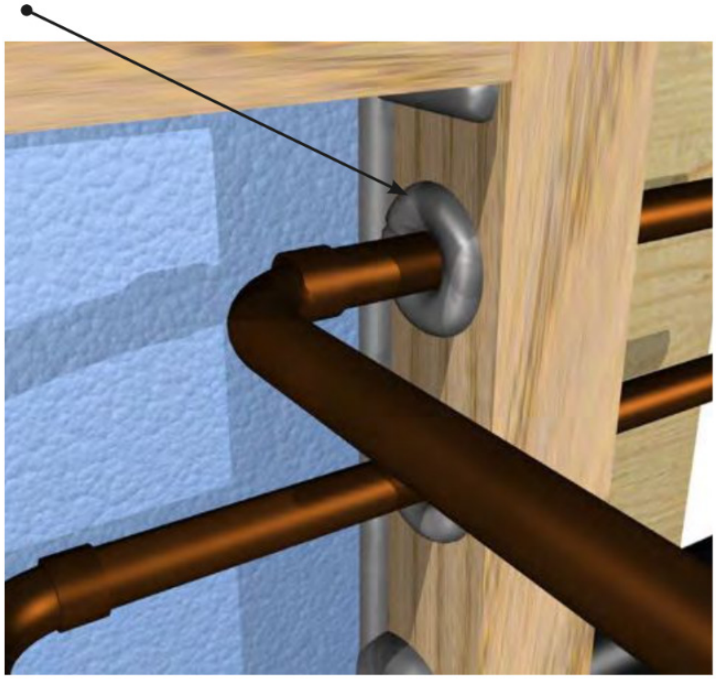




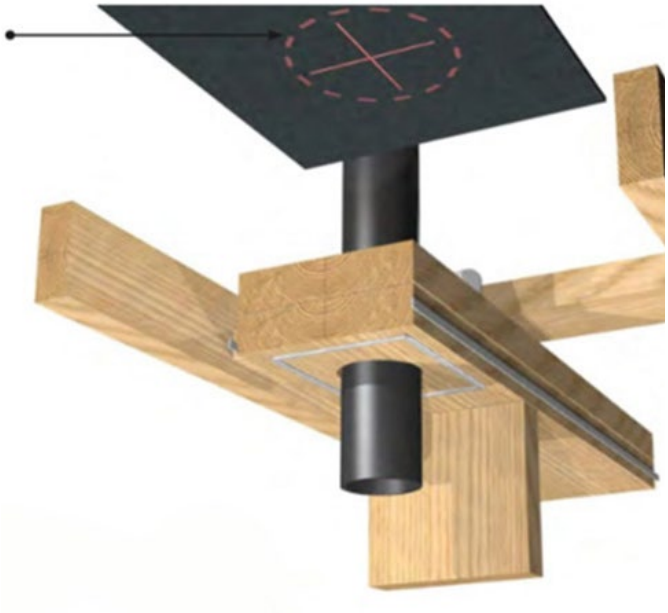
9. Examples of sealed polyethylene installation around the **windows and doors**

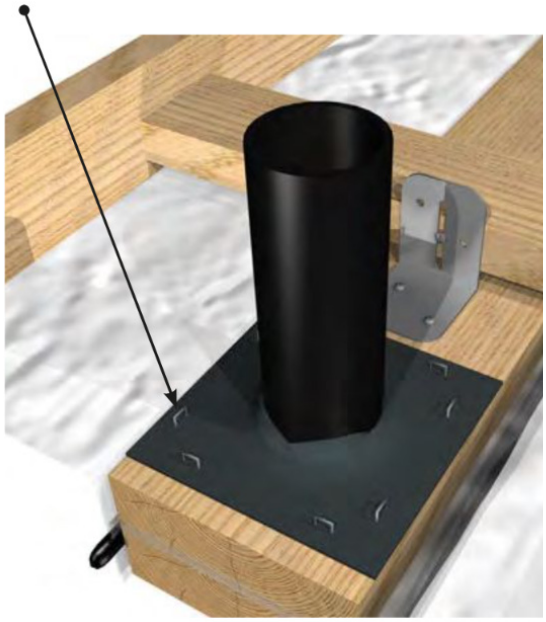


10. Example of sealing around the **pipes**



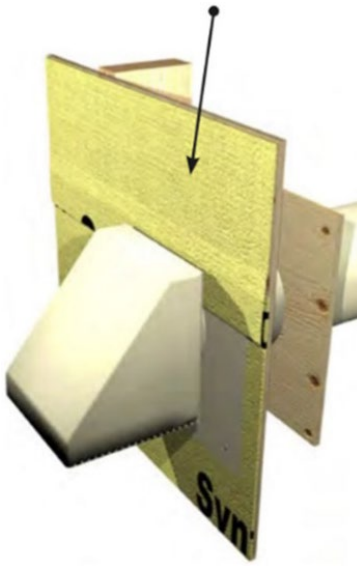
11. Examples of cutting a "+" or semi-circle through a gasket material less than the diameter of the pipe, then sliding the **gasket over the pipe** and sealing

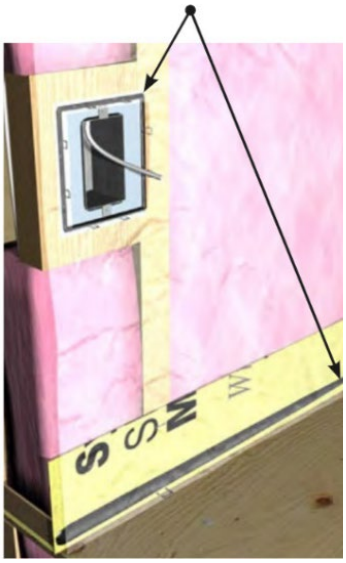


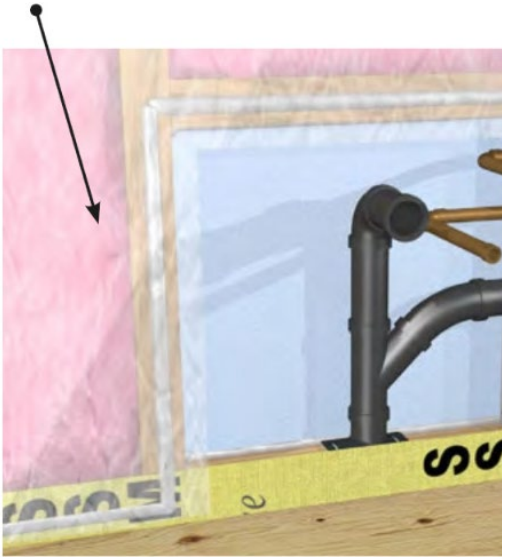


12. Example of sealed polyethylene installation around the **pipes**

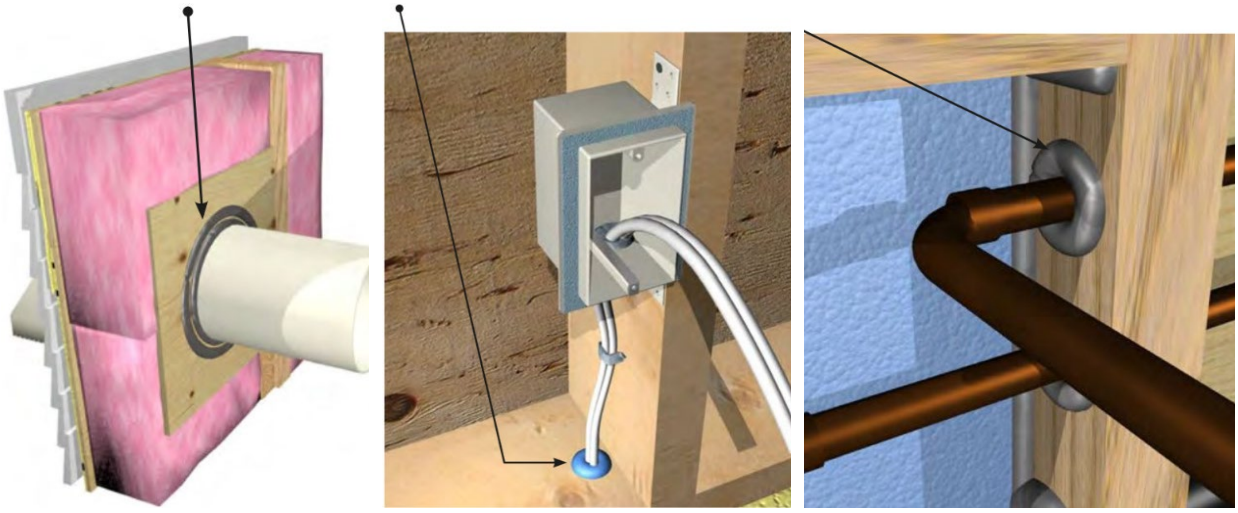
13. Examples of synthetic sheathing membrane and sealed polyethylene installation around the **mechanical/electrical/plumbing systems**



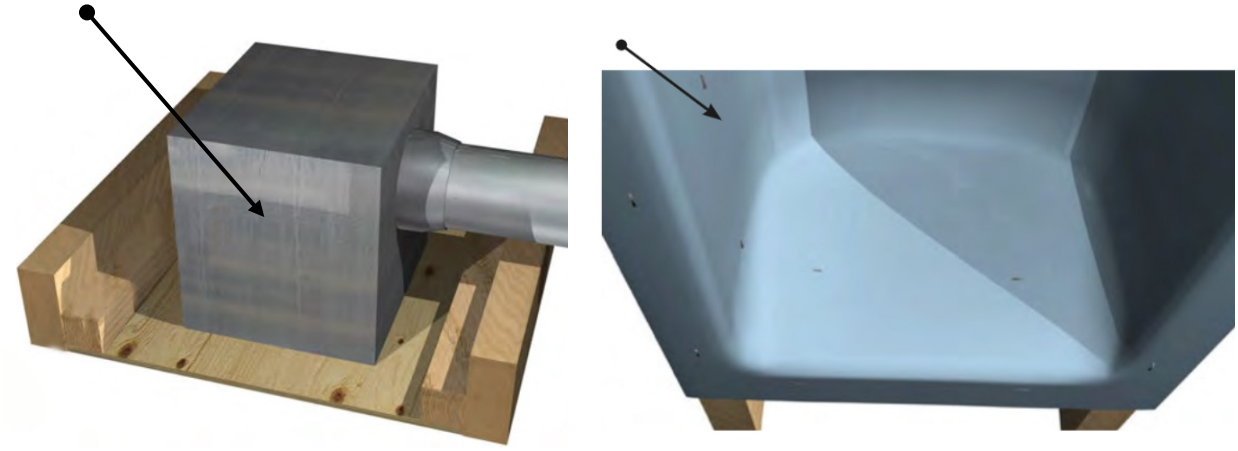




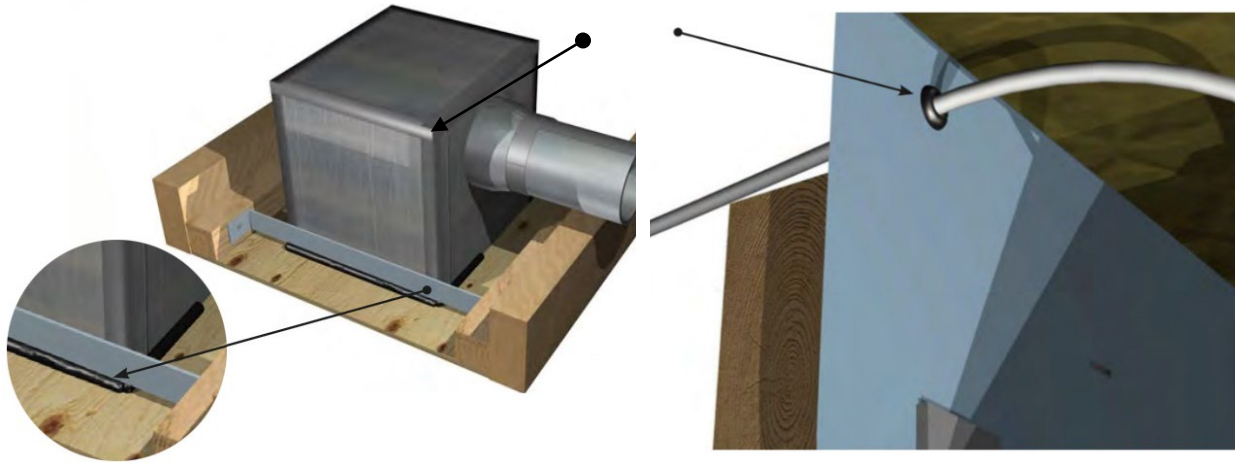
14. Examples of sealing around **mechanical/electrical/plumbing systems**



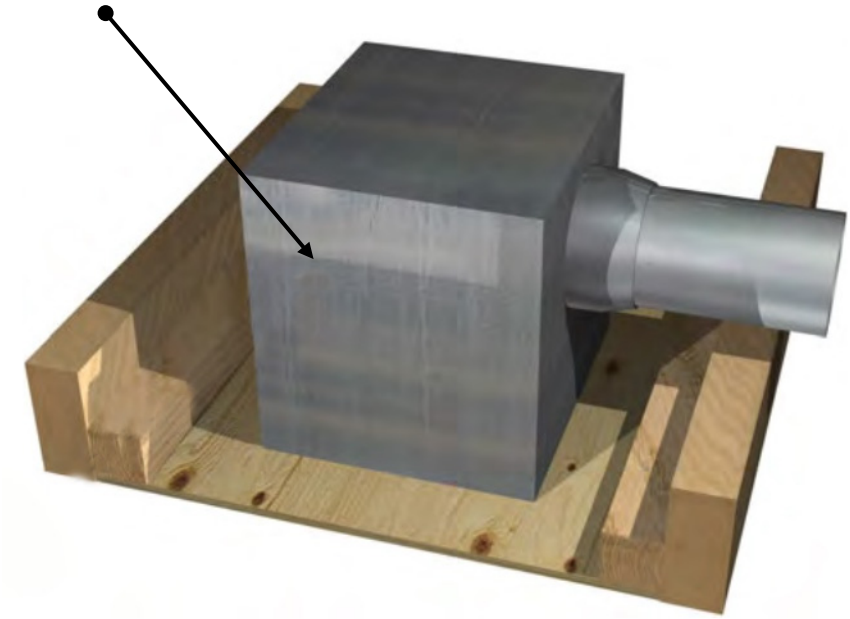
15. Examples of **airtight mechanical/electrical boxes**



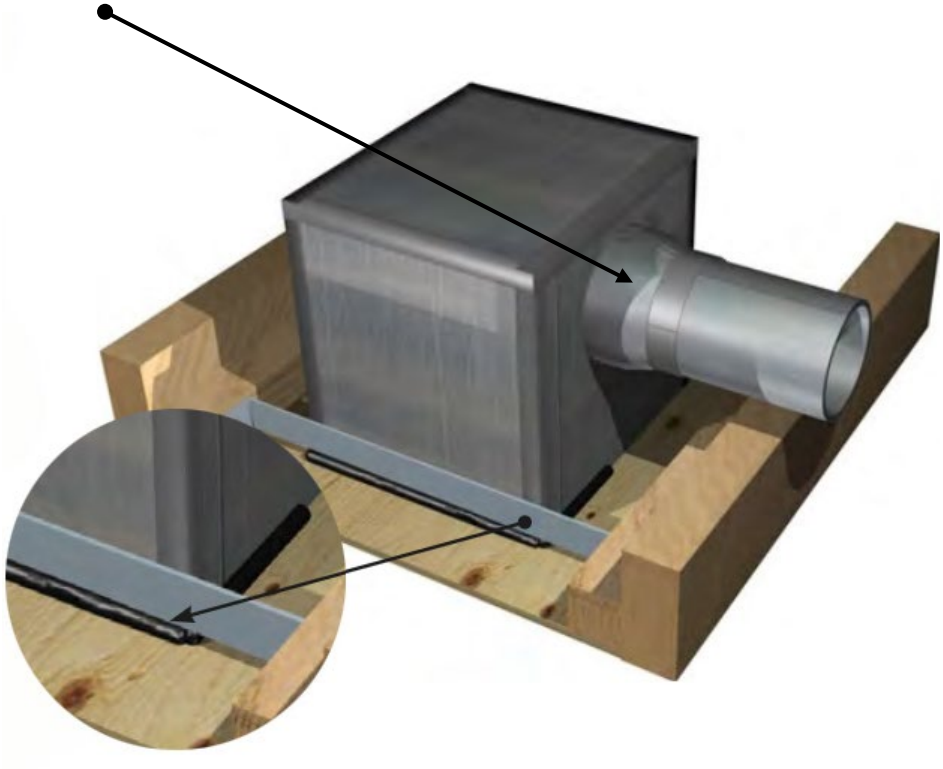
16. Examples of sealing around the **penetrations on airtight mechanical/electrical boxes**



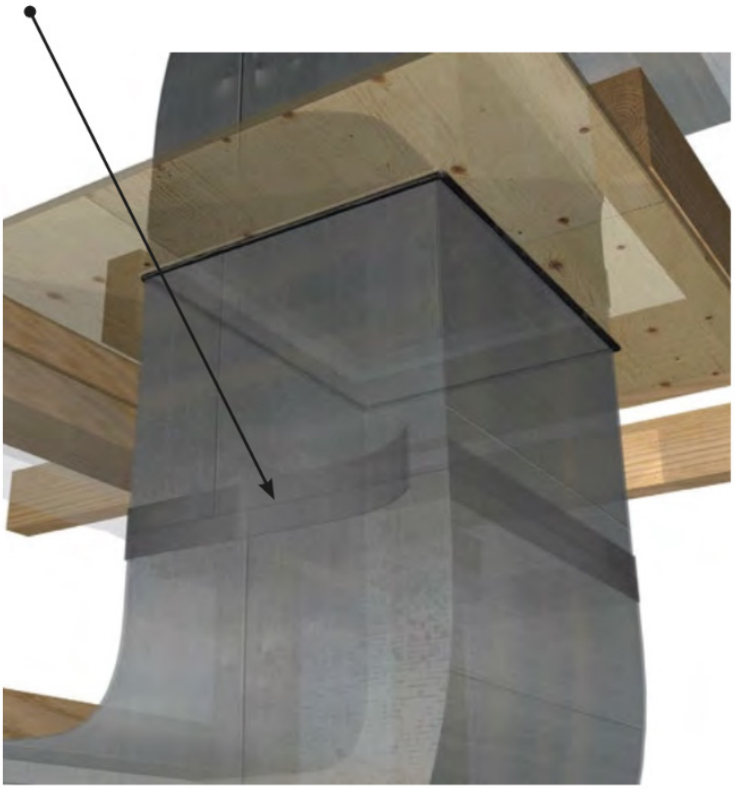
17. Example of **airtight mechanical boxes**



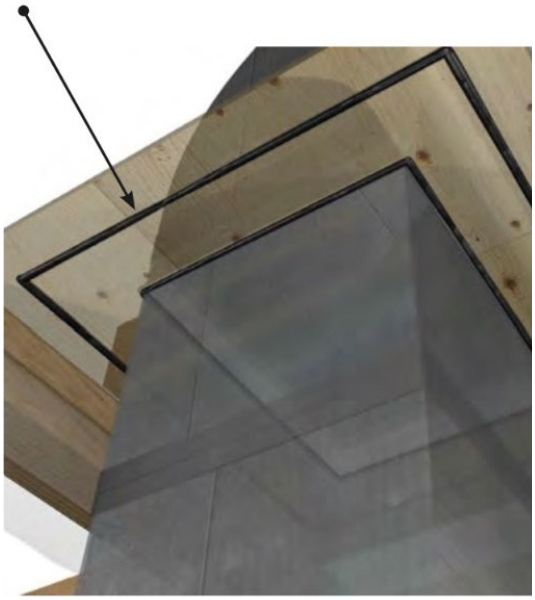
18. Example of sealing around the **penetrations on airtight mechanical boxes**



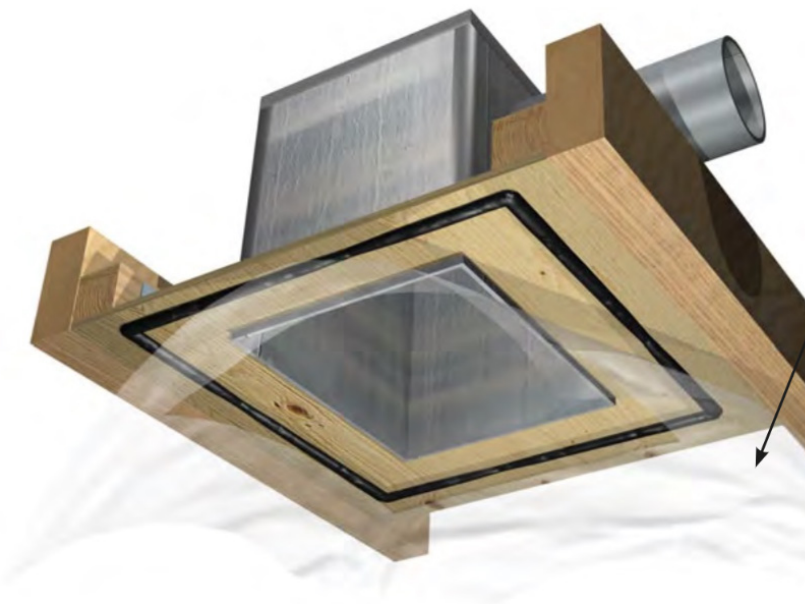
19. Example of foil-faced tape application to **mechanical ducts**

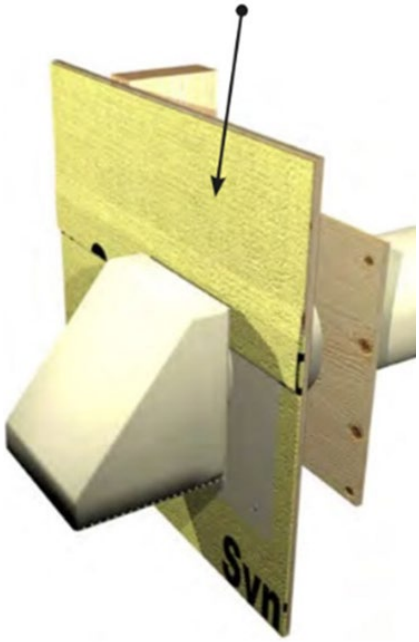


20. Examples of sealing around **HVAC equipment**



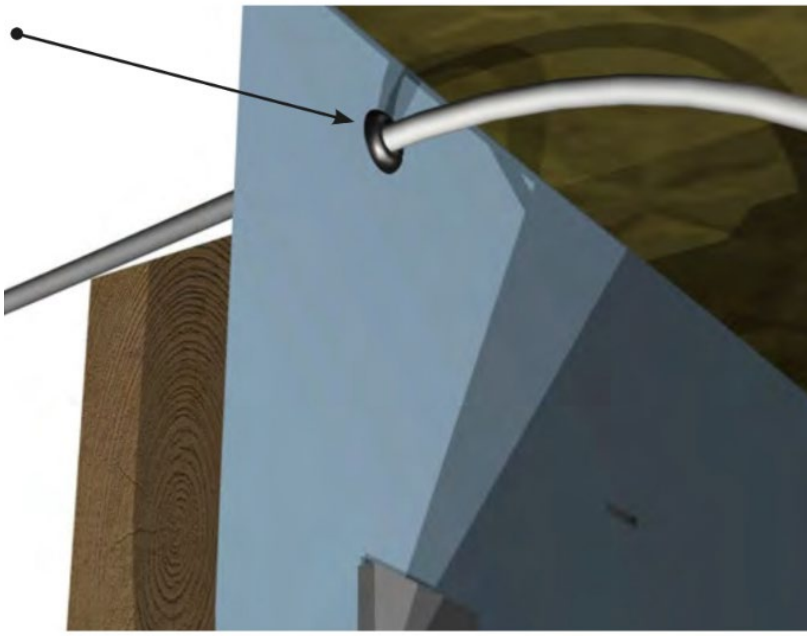
21. Examples of sealed polyethylene and synthetic sheathing membrane installation around the **HVAC equipment**

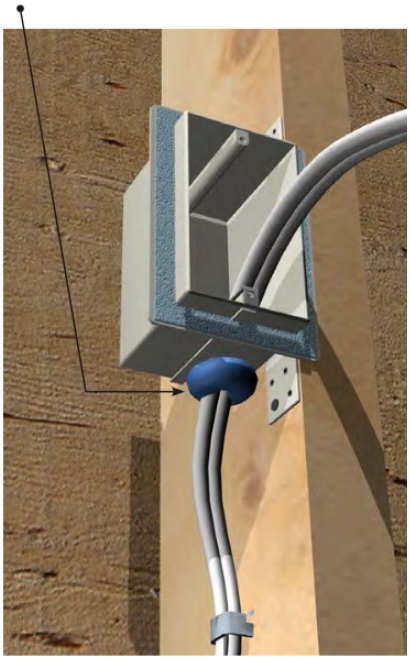




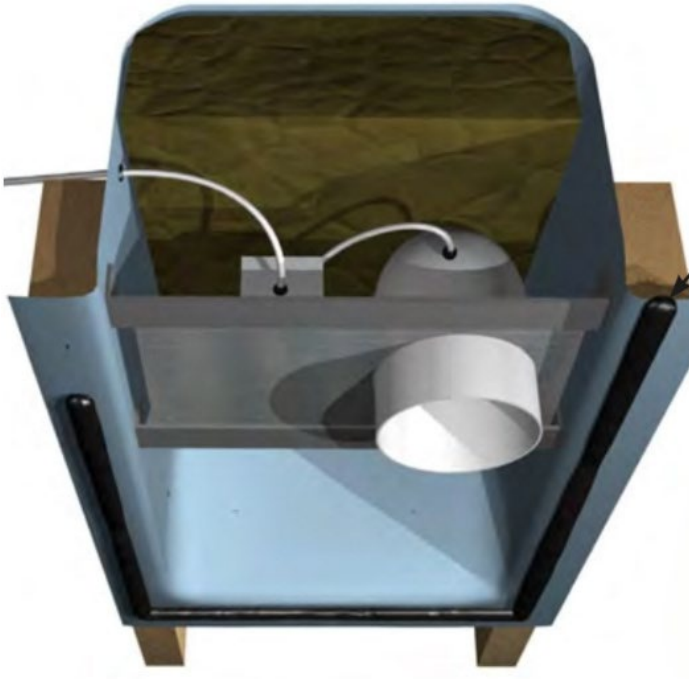
22. Examples of **airtight electrical boxes**

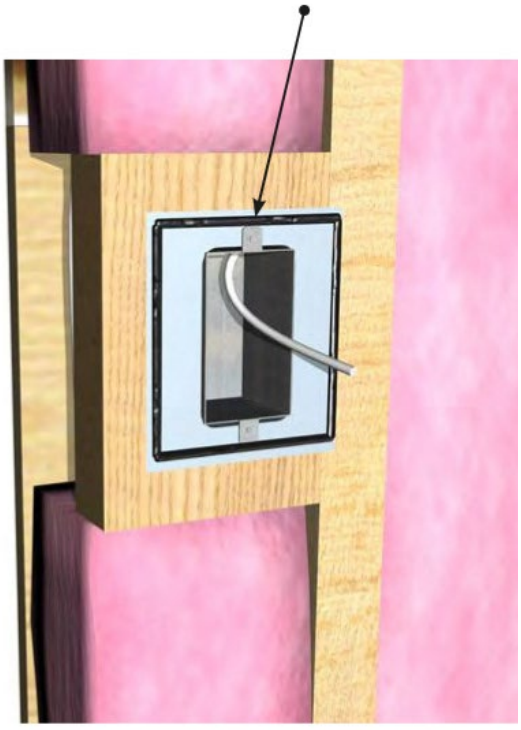
23. Examples of sealing around the **penetrations on airtight electrical boxes**



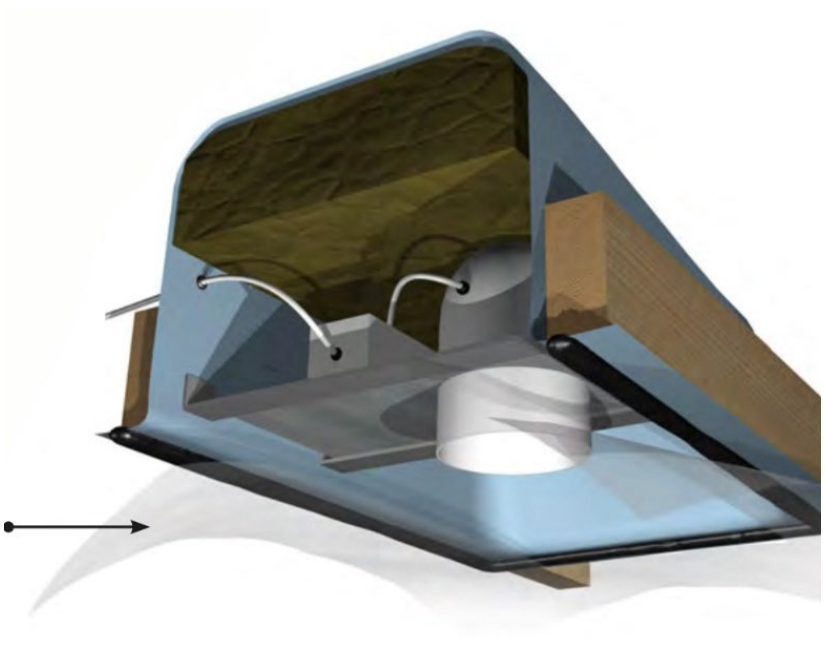


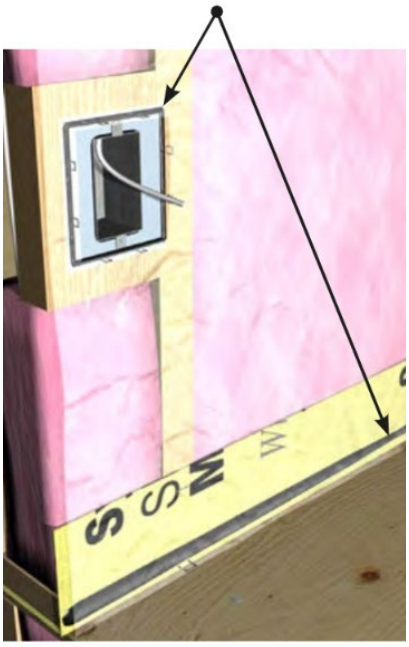
24. Examples of sealing around the **electrical equipment**



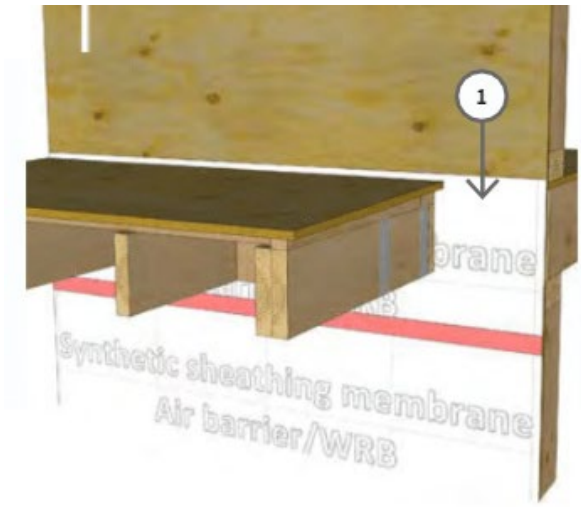


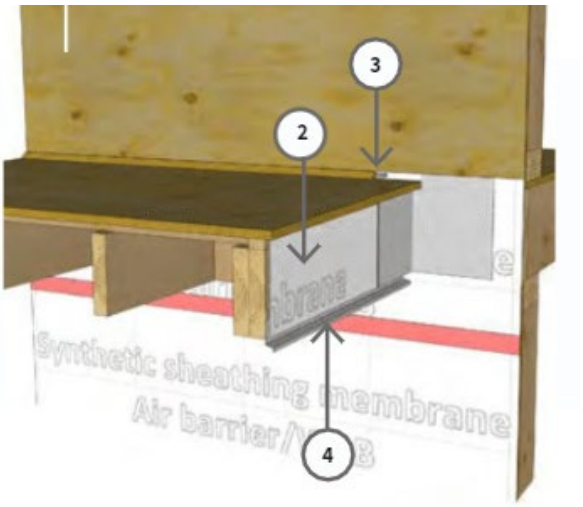
25. Examples of sealed polyethylene and synthetic sheathing membrane installation around the **electrical equipment**

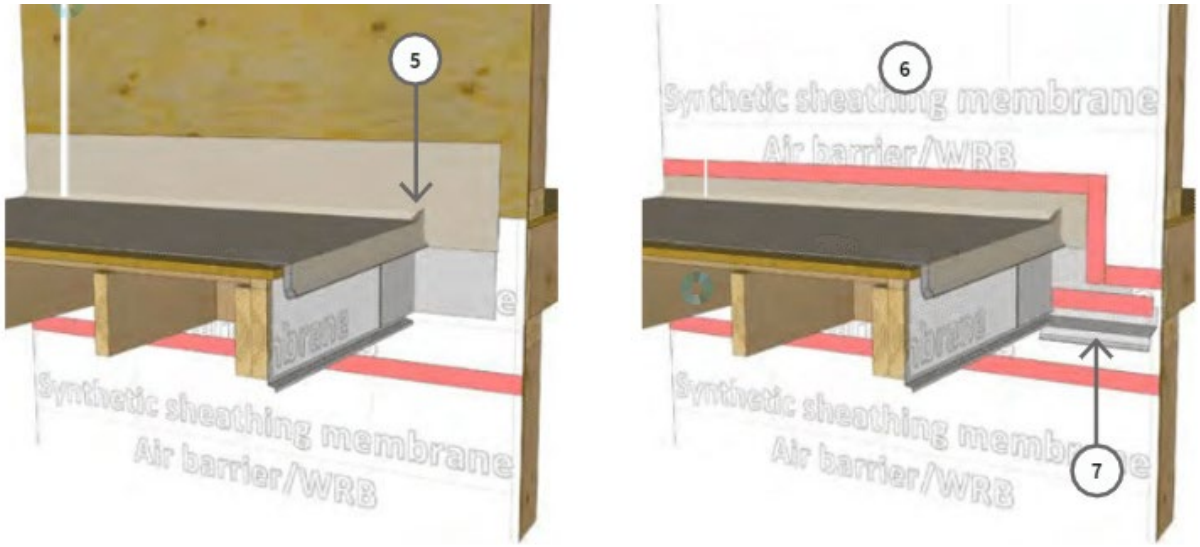




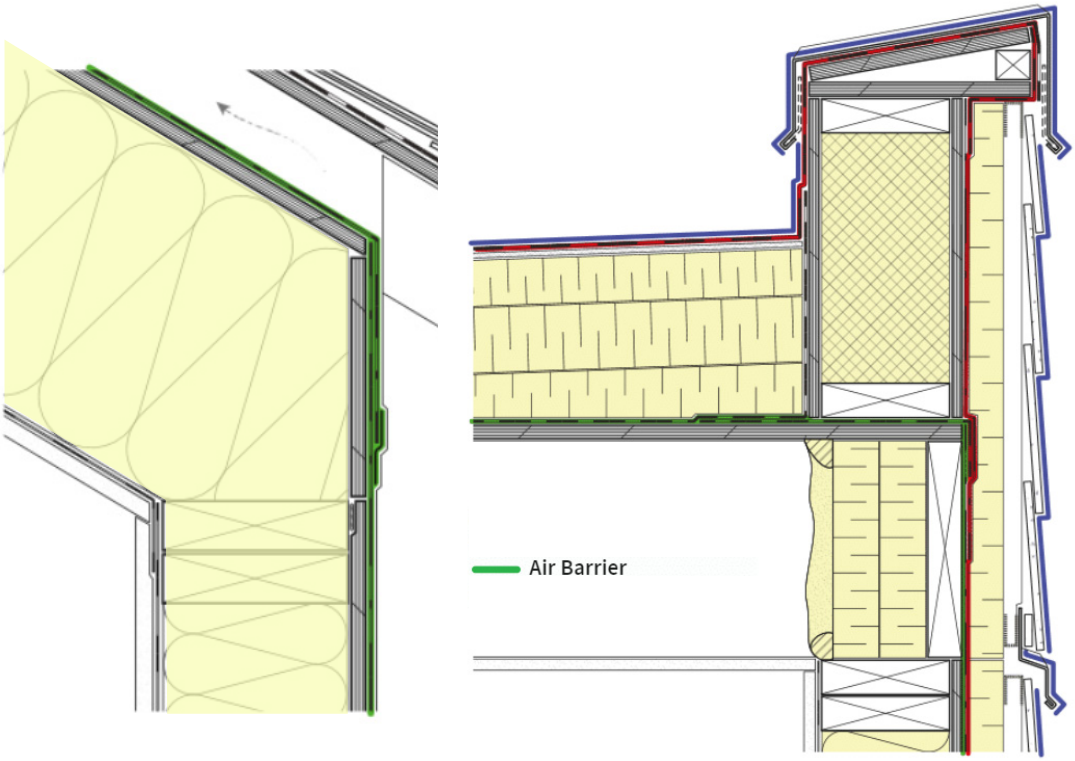
26. Examples of synthetic sheathing membrane installation around **exterior stairs, balconies, decks**



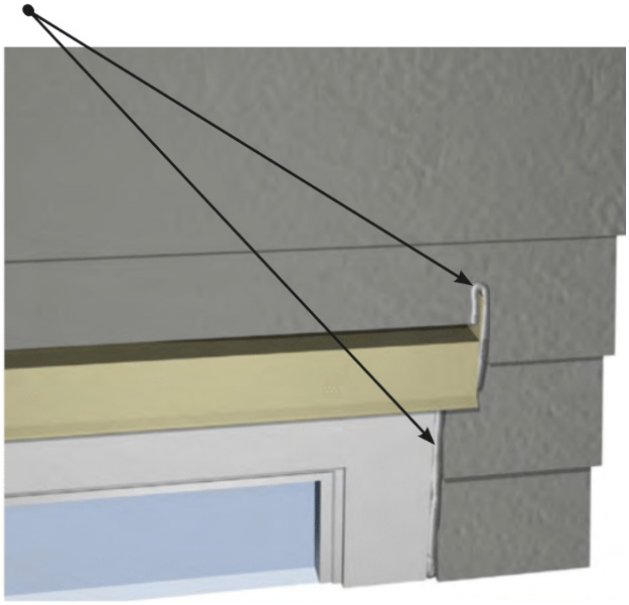


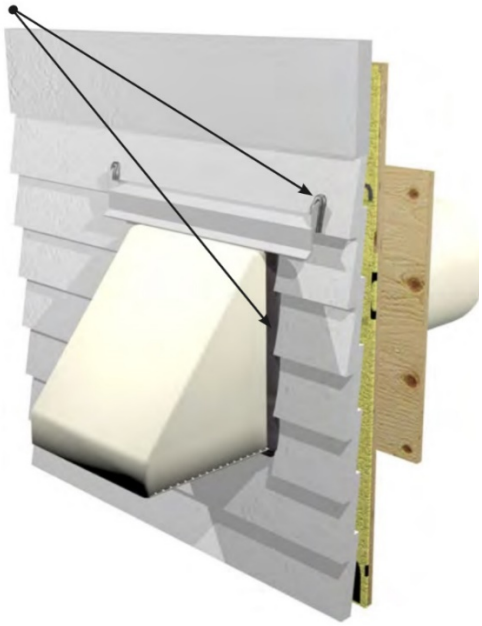


27. Examples of synthetic sheathing membrane installation around **roofs**



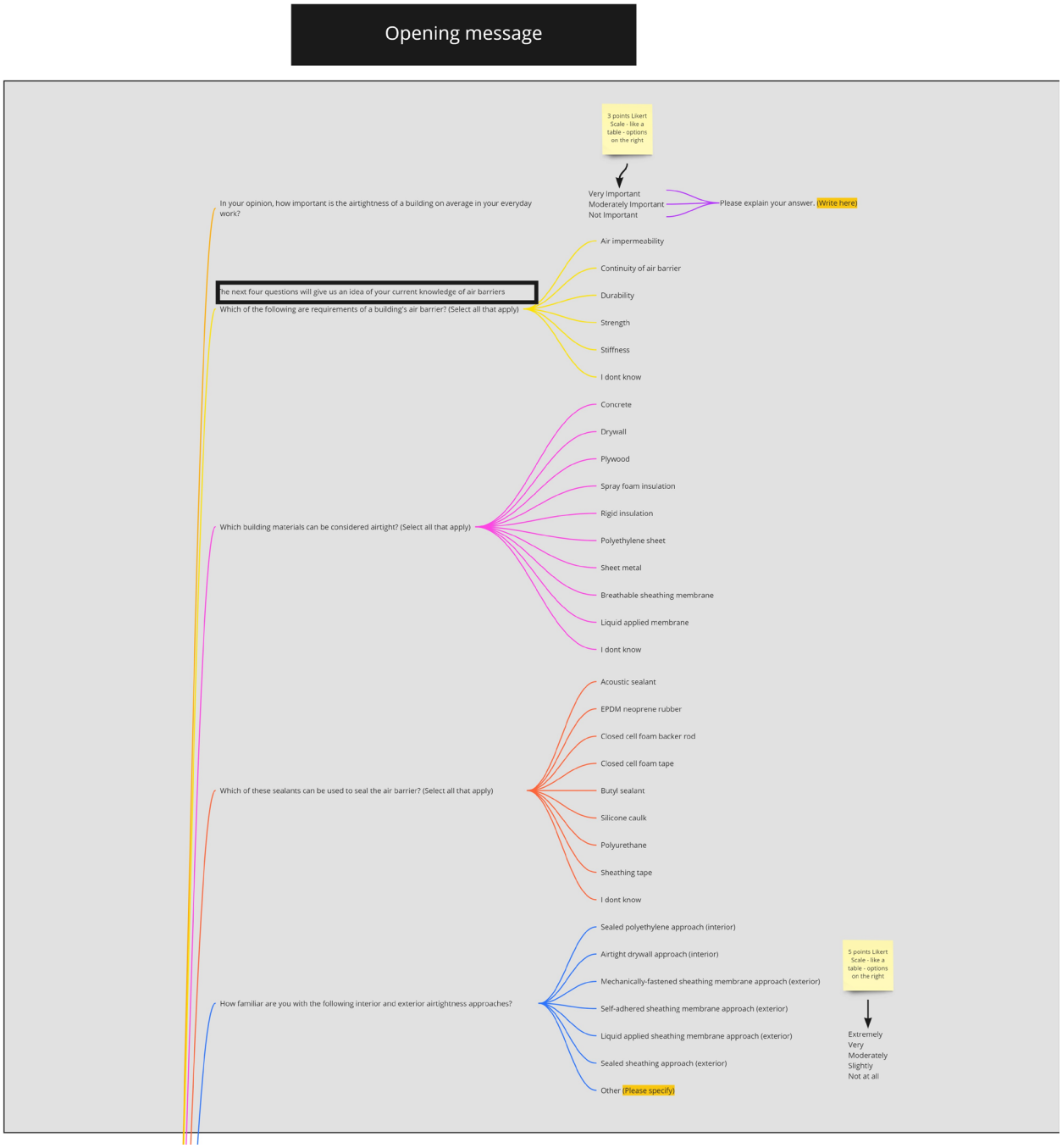
28. Examples of sealing around the **metal flashings**



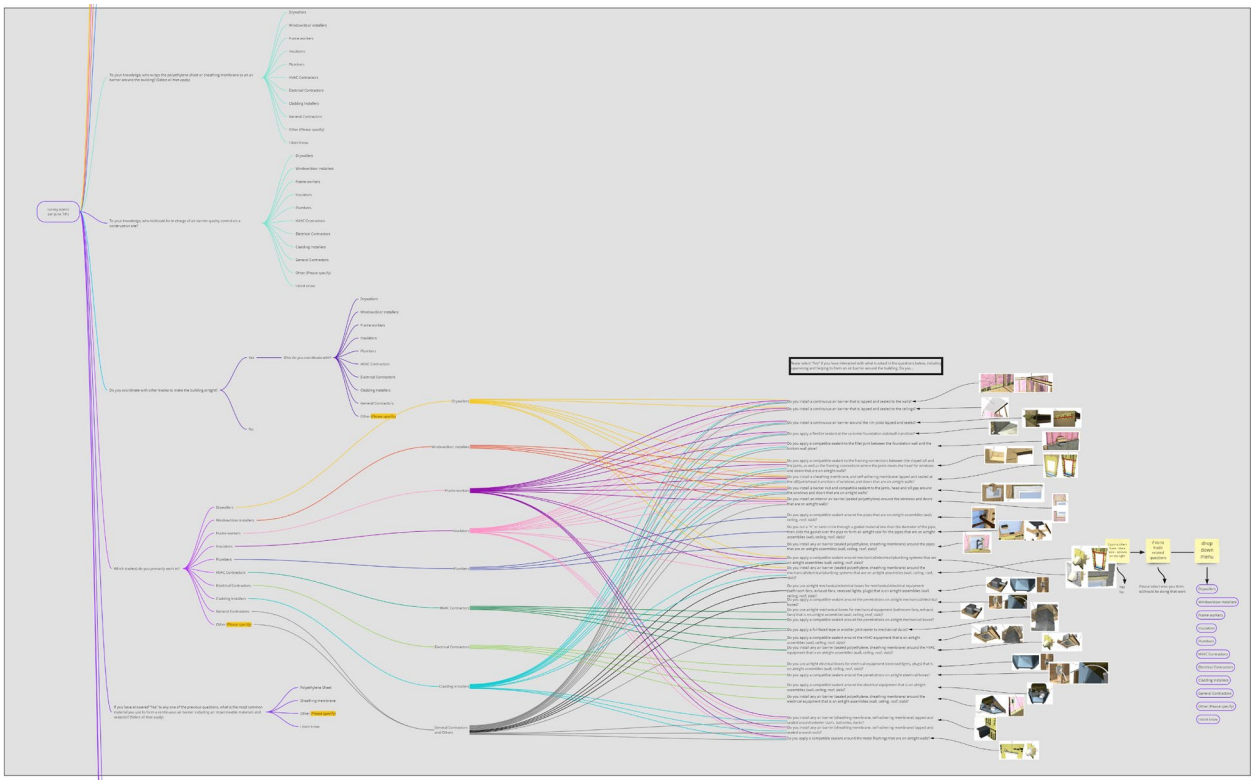


Appendix D Survey Questions Preparation Diagram

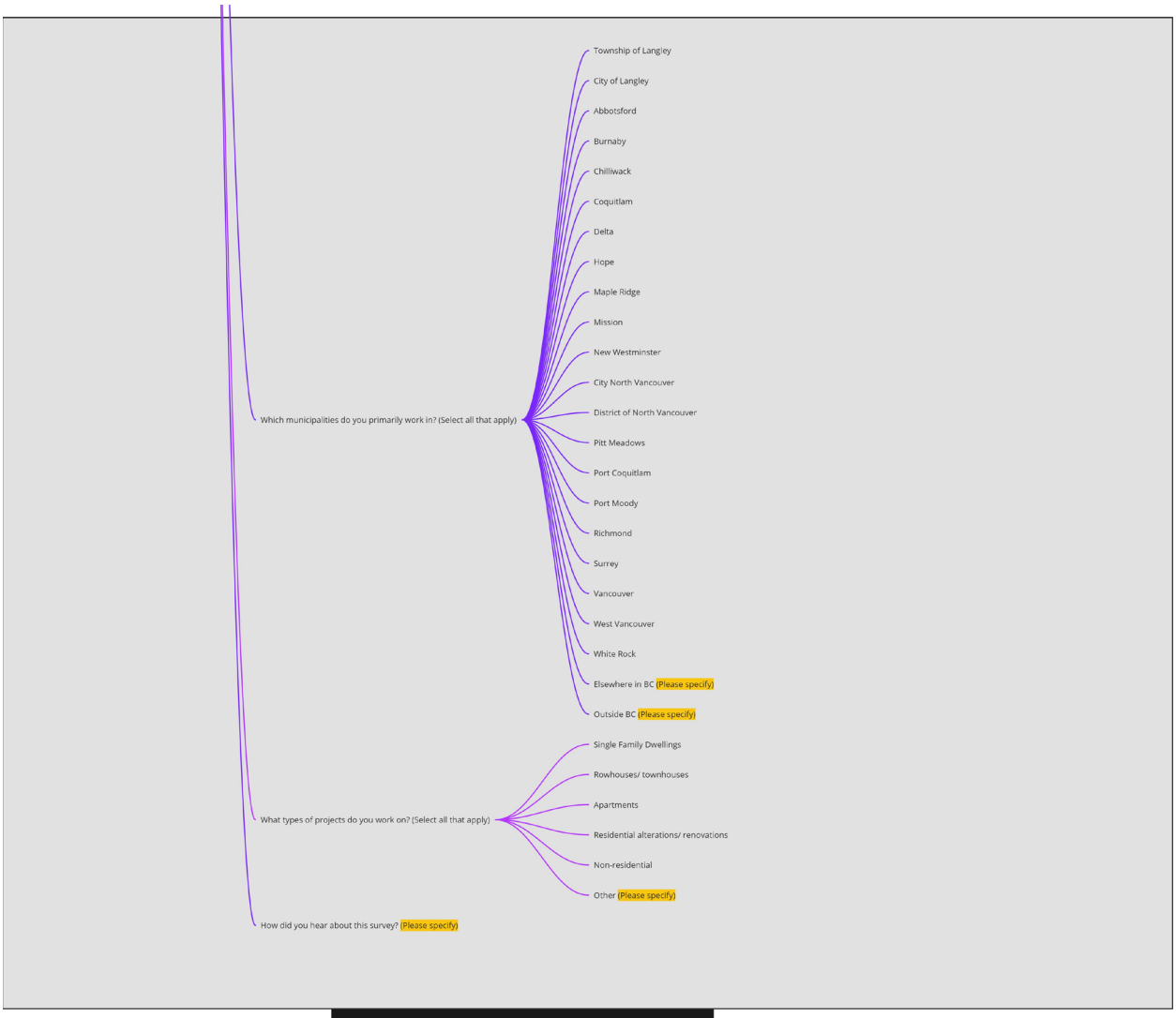
General questions



Technical questions



Demographics questions



Thank you message