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A Study of Electricians' Preferences of PVC and Alternative Conduit Materials in the State of Utah

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ABSTRACT

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Polyvinyl Chloride, commonly known as PVC is a common and effective construction material. PVC is also one of the most common types of plastic. In 2008, global production and consumption of PVC was approximately 34.5 million tons. The construction industry is responsible for about 70% of the world's consumption of PVC. The largest construction use of PVC is for pipe and conduit. Modern construction, especially structures built for data services depend heavily upon PVC conduit for underground pathways to distribute electricity and data. PVC is also at the center of a fierce effort by environmental groups who would like to see it eliminated completely.

If environmentalists are successful in their efforts to eliminate PVC; builders will be left without a material that is crucial for many applications. Seven alternative conduit materials have been identified as potential replacements for PVC electrical conduit.

PVC electrical conduit is commonly used in commercial, industrial, and civil construction. This thesis undertook to study the four major electrical contractors in the state of Utah which employ more than one hundred electricians. Because major electrical contractors use large quantities of PVC conduit, electricians working for these contractors were surveyed to determine their preferences of alternative materials. A questionnaire was distributed and received 112 responses, which represent 6.5% of the total population.

This study found that PVC was the most used, most preferred, easiest to install and was perceived as the least expensive conduit material. Polypropylene and High Density Polyethylene were rated next highest, but were also the least commonly used of the alternative materials. The other materials, which include: Nylon, Fiberglass, Fiberglass Reinforced Epoxy, Polyurethane Coated Steel, and Galvanized Steel were also examined. Many of the respondents expressed displeasure by the effort to eliminate PVC and the vast majority felt that green certification for

construction did not justify elimination. These responses indicate that more needs to be done to introduce alternative conduit materials to users of PVC and educate them about the value of the alternatives. This study represents an important step in evaluating the value of PVC conduit and its alternatives.

Keywords: Robert Andrus, PVC, polyvinylchloride, conduit, electrician, conduit alternatives, green conduit, green building, green materials, electrician preference.

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Polyvinyl Chloride, commonly known as PVC, is one of the most common types of plastic. Developed in 1872,[1] the first PVC was brittle and nearly useless. Through innovations in the manufacturing process, PVC has become a versatile plastic; accepting the widest variety of additives and having a vast range of applications. PVC is now found all around us; in clothing, flooring, computers, cell phones, automobile interiors, swim toys and construction materials.

[1] K. Mulder and M. Knot, "PVC plastic: a history of systems development and entrenchment", *Technology in Society*, no.23 (2001): 267.

PVC is naturally resistant to bacteria which makes it ideal for many construction applications but also makes it a target of environmental groups, who argue that is does not biodegrade.

In 2008, global production and consumption of PVC was approximately thirty-four and a half million tons.[2] PVC is most commonly used as construction material. "The principal uses of PVC, in order of importance are pipes, construction materials, consumer goods, packaging and consumer products such as wire and cable. Pipes, siding, windows, doors and profiles (gutters, fences, decks, etc.) together account for more than two-thirds of PVC use, and are among the fastest growing categories."[3] In 2002, forty-five percent of PVC sales were of pipe and conduit.[4] PVC is manufactured around the world by over one hundred companies in approximately fifty countries.[5] PVC has proven to be an extremely versatile and popular material, however; it has also become the center of a fierce effort by environmentalist who would like to see PVC eliminated all together.

Since the late 1980's the environmental group Greenpeace has been campaigning for the elimination of PVC.[6] Greenpeace has been joined by many voices including; the Healthy Building Network,[7] the World Watch Institute[8] and the Cascadia Region Green Building Council.[9] Another organization, The U.S. Green Building Council, which administers the most

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[2] E. Linak, *Chemical Economics Handbook*, (SRI Consulting, 2009); available from http://www.sriconsulting.com/CEH/Public/Reports/580.1880/; Internet; accessed 19 September 2009.
[3] F. Ackerman, *Poisoned for Pennies: The Economics of Toxics and Precaution* (Washington DC: Island Press, 2008), 166.
[4] E.Linak and K. Yagi, *Polyvinyl Chloride (PVC) Resins: Chemical Economics Handbook Marketing Research Report* (California: SRI International, September, 2003); quoted in F. Ackerman, *Poisoned for Pennies: The Economics of Toxics and Precaution* (Washington DC: Island Press, 2008),166.
[5]E. Linak, *Chemical Economics Handbook*, (SRI Consulting, 2009) available from http://www.sriconsulting.com/CEH/Public/Reports/580.1880/, Internet; accessed 19 September 2009.
[6] Greenpeace, "Go PVC-Free," available from http://www.greenpeace.org/usa/campaigns/toxics/go-pvc-free; Internet; accessed 8 August 2009.
[7] Healthy Building Network, "PVC-Free Agenda makes Sense," available from http://www.healthybuilding.net/press/plastics_news_opition.html; Internet; accessed 25 September 2009.
[8] P. McRandal, "Green Guidance," *World Watch Magazine*, no. 19 (March/April 2006): 2
[9] Cascadia Region Green Building Council (GRGBC), *The Living Building Challenge: In Pursuit of True Sustainability in the Built Environment* (Portland Oregon, 2007), 20.

widely recognized standard for green building called the Leadership in Energy and Environmental Design (LEED), is currently considering the issue through its technical advisory board.[10]

The effort to eliminate PVC has been effective through a two-pronged approach. The first approach has been implemented through aggressive marketing directly to consumers of PVC to encourage the use of alternative materials over PVC. The second approach has been through direct government regulation of PVC and the materials used to make it. In particular this legislation has focused on regulating the use of chlorine, plasticizers and lead stabilizers. Many of these environmental groups make the argument that PVC releases toxins throughout its life cycle from manufacture to disposal. PVC is inherently flame retardant, but when burned it has the potential to release chlorine gas. When chlorine gas is combined with moisture it produces hydrochloric acid as well as dioxins, both of which have been shown to threaten human health even at low concentration levels.[11]

The possibility of PVC being eliminated is real and many European countries have already passed legislation restricting its use. In the United States, environmental legislation first began in 1972 with the forming of the Environmental Protection Agency (EPA). Since that time environmental legislation has expanded and become increasingly strict. Currently, government leaders appear willing to place tougher regulations on toxins and pollutants which may be harmful to the environment. With fears of global warming and marketing appeals for "Going Green" the general public has become environmentally conscious. These current trends add to the probability that PVC may be eliminated.

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[10] U.S. Green Building Council (USGBC), "USGBC: PVC Task Group Background and History," available from http://www.usgbc.org/displaypage.aspx?CMSPageID=153 Internet; accessed 29 August 2009.
[11] F. Ackerman, *Poisoned for Pennies: The Economics of Toxics and Precaution* (Washington DC: Island Press, 2008),164-165.

If PVC is eliminated or phased-out the construction industry will be affected as builders will be left without a material that is commonly used for many applications. Given the potential risk of government restriction on the use of PVC and consumer demand for more environmentally friendly products, users of PVC should become familiar with the most viable alternative options.

The construction industry is responsible for about seventy percent of the world's consumption of PVC.[12] The largest construction use of PVC is for pipe and conduit. Electricians involved with commercial construction are major users of PVC conduit. PVC conduit has already been restricted by building code limitations for above ground use and is now primarily used underground. If electricians are no longer permitted to use PVC conduit underground, then alternatives should be identified and analyzed to determine which material is best suited to take its place. A number of factors should be considered to determine the best alternative including; the cost of material, the speed or ease of installation, the preference of the installer, and the environmental friendliness of the material to avoid further conflict with environmental groups.

1.2 Problem Statement

PVC, a chemical used to make common construction materials such as pipe and conduit, has been targeted by environmental groups for elimination. The construction industry may be faced with the necessity to replace this material. In light of this possibility it is important to understand electricians' awareness and preference for alternative underground conduit options.

[12] E. Linak, *Chemical Economics Handbook*, (SRI Consulting, 2009) available from http://www.sriconsulting.com/CEH/Public/Reports/580.1880/, Internet; accessed 19 September 2009.

1.3 Need for the Study

This study is valuable to the construction industry in identifying the most preferred alternative conduit materials by electricians for three reasons: first; to be aware of possible restrictions on PVC for underground use, second; to meet consumer demand for green building certifications it may be necessary to replace PVC with alternative materials and third; to determine electricians' awareness of and preference for alternative underground conduit materials.

1.4 Statement of Research

This study sought to clarify and evaluate the preferences of electricians working in the state of Utah for more environmentally friendly alternatives to PVC conduit in underground electrical applications. This was accomplished through the identification of trends, forces and alternative materials found in the literature and by surveying the preferences of over one hundred practicing commercial electricians in the state of Utah.

1.5 Purpose of the Study

The purpose of this research was to identify and evaluate the preferences of electricians in the state of Utah for PVC and alternative conduit materials used in underground electrical applications.

1.6 Uniqueness of the Study

A review of literature and positions of various environmental groups has shown that other research is available on the pros and cons of PVC. This study adds to the available knowledge by focusing specifically on the awareness and preference of electricians' in the state of Utah for alternative underground conduit.

1.7 Limitations

1. It was beyond the scope of this study to measure all products containing PVC. This study focused solely on PVC for underground electrical conduit.
2. The scope of this study was limited to documenting the positions behind the elimination of PVC. This study was not intended to debate the science behind the push for the elimination of PVC but to acknowledge the debate and the possible implications of the debate for electrical contractors in the construction industry.
3. The "environmentally friendly" alternatives to PVC conduit for underground electrical use were identified by environmental groups pushing for the elimination of PVC. The analysis of the "environmental friendliness" of these alternatives was beyond the scope of this study.
4. This scope of this study was limited to the preferences of electricians working for major electrical contractors in the state of Utah. However, there is no reason to assume that preferences of electricians should vary greatly by region, or from state to state.

1.8 Assumptions

1. As users of PVC and other conduit, electricians are well suited to evaluate the use of various alternative materials.
2. PVC has been identified as a product for elimination in both rigid and flexible applications; therefore, PVC conduit will also be eliminated. It will need to be replaced by some other type of conduit or pipe material.

1.9 Definition of Terms

1. **Polyvinyl Chloride:** The combination of the Vinyl Monomer and Chlorine. Used in rigid and flexible applications, accepts a wide range of additives including plasticizers and stabilizers, also known as PVC.
2. **PVC Conduit:** PVC pipe which is used primarily as a pathway for electrical cables, rather than for liquids.
3. **Green Building:** "The practice of creating structures and using processes that are environmentally responsible…[13]"
4. **Greenpeace:** An international campaign organization dedicated to environmental causes.
5. **Leadership in Energy and Environmental Design Certification:** The most widely recognized and in some cases government approved standard for green building certification, implemented by the United States Green Building Council, also known as LEED.

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[13] U.S. Environmental Protection Agency, Green Building Basic Information, available from www.epa.gov/greenbuilding/pubs/about.htm; Internet; accessed 15 June 2009.

6. **The United States Green Building Council:** A non-government agency which administers LEED certification, also known as the USGBC.

7. **Living Building Challenge:** A new standard for building as developed by the Cascadia Region Green Building Council, meant to surpass LEED as a higher level of green building standard, also known as the LBC. To date no structure has been certified as a Living Building.

8. **Cascadia Region Green Building Council:** A non-government agency which administer the Living Building certification, also known as the CRGBC.

9. **Materials Red List:** A list of materials compiled by the CRGBC which may not be present in construction for a building to be eligible to receive Living Building status.

10. **Sustainable Building:** A building that can operate independently of outside resources provided through civil services such as power, electricity and sewage.

11. **Plasticizers:** An additive which make PVC more flexible.

12. **Stabilizers:** An additive which makes PVC more rigid.

13. **Organochlorines:** An organic compound that contains at least one covalent bond to chlorine, also known as an organochloride.

14. **Phthalates:** A chemical primarily used as a softener of PVC plastic, also known as phthalic acid.

15. **Dioxins:** An environmental pollutant which can be released from PVC when it is burned, also known as polychlorinated dibenzodioxins or polyhalogenated chlorines.

16. **Organohalogens:** Any organic compound which contains at least one halogen.

17. **Halogen:** Any of five non-metallic elements: fluorine, chlorine, bromine, iodine and astatine.

18. **Chlorine:** A non-metallic element halogen. Chlorine is also the primary ingredient in PVC.

19. **Volatile Organic Compounds:** Materials that may emit harmful chemicals or odors such as certain types of paint or finishes, also known as VOC.

20. **High Density Polyethylene:** A non-chlorinated alternative to PVC pipe which requires fewer additives and has a much higher recycling rate, also known as HDPE. HDPE is less resistant to combustion, although it does not release hydrochloric acid before combustion.

21. **Polypropylene:** An alternative to PVC pipe which is made from the monomer propylene and shares many of the strengths of PVC. It is chemical resistant, flame retardant and light weight. This pipe is useful for industrial applications involving corrosive media, also known as PP or Poly.

23. **Galvanized Steel:** An alternative to PVC pipe which is a created by coating traditional steel with zinc; this provides a resistance to corrosive environments and rust. Despite its corrosion protection, Galvanized Steel does not stand up to chemical environments as well as plastics.

24. **Fiberglass:** An alternative to PVC pipe which is created by combining glass fibers with a polymer resin; resulting in a high strength, low weight product. Because of the strength of the fiberglass material it may be buried directly without concrete encasement.

25. **Fiberglass Reinforced Epoxy:** An alternative to PVC pipe which is similar to fiberglass pipe but uses a plastic product instead of resin, also known as FRE. This pipe is commonly used in marine settings.

26. **Nylon:** An alternative to PVC pipe, commonly used in plumbing and fittings which is available at local hardware stores. Nylon is most commonly found as the pipe product called, Liquatite or Liquid Tight Conduit. For underground applications, Liquid Tight is often found in the form of a corrugated flexible steel conduit coated with Nylon for corrosion protection.

27. **Polyurethane Coated Steel:** An alternative to PVC pipe which is created by coating steel with polyurethane for chemical resistance, also known as PCS. PSC can also be found in the form of tubing used for a number of applications, but it does not have the strength required to withstand the load of direct burial or concrete encasement.

28. **ISO 14001 and ISO 21391:** A general frame work for improving the quality and comparability of methods for assessing the environmental performance of buildings which is published by the International Organization for Standardization and promoted by the United Nations.

REVIEW OF LITERATURE

2.1 Introduction

Figure 2.1: Construction Workers at Lunch

A famous photograph taken in 1932, high above the Rockefeller center in New York City, shows a group of construction workers sitting on a steel beam eating lunch, twenty-three stories above the city street. None of them wore hardhats, safety glasses, reflective vests, eye or ear protection, none of them wore safety harnesses or any type of fall protection. A modern picture would be very different. Safety is just one example of how the construction industry in 2009 has become a highly regulated environment. Today, nearly every aspect of construction is overseen by some government agency requiring reports and approval. The design, safety and materials of a structure are all subject to regulations, approval from city planners, inspectors and agencies. For years the government has regulated what materials may be used in construction.

Asbestos is an infamous example of a construction material that was once widely used. Asbestos was later shown to cause cancer in certain situations and was eventually eliminated from new construction and from many existing structures. Today there is a chance that another common construction material may be eliminated. Polyvinyl Chloride (PVC) has been targeted by groups such as Greenpeace, The Healthy Building Network (HBN) and Cascadia Region Green Building Council (CRGBC) for elimination. The United States Green Building Council (USGBC), which administers the Leadership in Energy and Environmental Design Certification, otherwise known as LEED, is currently studying the debate about PVC to determine if they will support elimination. If PVC is banned by government regulation, or phased out to comply with green building standards, acceptable alternatives must be identified so that builders are not left without an important underground conduit material.

The following review of literature will document a brief history of government and environmental regulation of the construction industry, the trend of green building and its influence on construction, an overview of PVC, green building organizations and their call for the elimination of PVC, and a few alternatives which have been recommended for replacement of PVC conduit for underground electrical use.

2.2 The Construction Industry

The construction industry is classified as comprising those companies which are primarily engaged in the construction of buildings or engineering projects, at all stages of completion, from land development to alterations on existing work. Companies classified as part of the construction sector are generally managed at a fixed place of business, while participating in any number of construction activities at multiple project sites. Construction is one of the largest industries in the United States. In 2006, there were about eight hundred and eighty-three thousand construction establishments in the United States, with over seven and a half million employees receiving wages or salary, and approximately an additional two million self-employed or unpaid family workers. Of those establishments, only one percent employed one hundred or more workers.[14] As of July 2009, there were approximately six million, one hundred and forty-eight thousand persons employed in the United States construction industry. Electricians are an important part of the construction industry, at last census, in 2008; there were more than four hundred and eighty-seven thousand electricians, approximately eight percent of the total employment in the construction industry.[15] In the state of Utah there are currently four electrical contractors employing one hundred or more electricians.[16]

2.3 Government Regulation of the Construction Industry

Since the early 1900's building regulations in the United States have been based on model building codes developed by three regional groups; the Building Officials Code Administrations International (BOCA), the Southern Building Code Congress International (SBCCI) and the International Conference of Building Officials (ICBO). These three groups were responsible for regional regulatory standards across the United States. As the country grew

[14] U.S. Department of Labor, Bureau of Labor Statistics, "Career Guide to Industries: Construction," available from http://www.bls.gov/oco/cg/cgs003.htm; Internet; accessed 15 August 2009.
[15] U.S. Department of Labor, Bureau of Labor Statistics, "Construction: NAICS 23," available from http://www.bls.gov/iag/tgs/iag23.htm; Internet; accessed 29 August 2009.
[16] The Associated General Contractors of Utah, "Member Directory," available from http://www.agc-utah.org/directory.html#bf-dirFrame_598; Internet; accessed 24 August 2009.

it became clear that a single coordinated set of building codes, without regional limitations, was necessary. In response, these groups decided to combine efforts and formed the International Code Council (ICC) in 1994.[17] The primary objective of the ICC is to protect “the health, safety, and welfare of people by creating better buildings and safer communities,”[18] through high-quality codes, products and services in order to create excellence and safety in the built environment. After its formation in 1994, the ICC then began developing an International Building Code (IBC) that could be used through out the United States. The first IBC was published in 2000. Currently, all fifty states plus Washington D.C. have adopted the IBC.[19]

In addition to the IBC, construction is also regulated by national and local government agencies. These regulations go beyond the scope of the IBC and may determine the location of buildings, their occupational ratings and their appearance. Government regulations may also affect which types of materials may be used, as well as construction safety requirements.

2.4 Environmental Regulation of the Construction Industry

In July of 1970, the United States Government formed the Environmental Protection Agency (EPA) in response to growing concerns for cleaner air, water, and land. Since that time, it has been the mission of the EPA to protect human health and the environment. In an effort to fulfill that mission the primary objectives of the EPA are to repair damage to the natural environment and to establish new criteria which will guide Americans toward a cleaner

[17] International Code Council, Introduction to the ICC, available from http://www.iccsafe.org/news/about/#origin; Internet; accessed 29 August 2009.
[18] International Code Council, Introduction to the ICC, available from http://www.iccsafe.org/news/about/#origin; Internet; accessed 29 August 2009.
[19] International Code Council, International Code Adoptions, available from http://www.iccsafe.org/government/adoption.html; Internet ; accessed 29 August 2009.

environment.[20] This is primarily fulfilled through laws that are administered by the EPA. These laws directly affect the construction industry. Examples include; the National Environment Policy Act (NEPA), the Pollution Prevention Act (PPA) and the Occupational Safety and Health Act (OSHA).

The NEPA was one of the first laws to establish a national framework for protecting the environment. “NEPA's basic policy is to assure that all branches of government give proper consideration to the environment prior to undertaking any major federal action that significantly affects the environment.”[21] This policy affects the construction of any major federal construction projects, such as highways, airports, military buildings etc. [22]

The PPA was established with the goal of reducing pollution through cost-effective changes in raw material use, production and operation, as well as increased efficiency in the use of natural resources and conservation.[23] This policy affects construction from pre-planning to completion so that waste is prevented or reduced at the source.

The OHSA was established to ensure worker and workplace safety. The underlying goal of OHSA is to ensure that employers’ provide their workers with a safe environment, free from known hazards to safety and health.[24] OHSA was the first nation wide, federal program with the goal of protecting the work force from job related death, injury or illness. OSHA regulates the construction industry by ensuring that conditions are made as safe as possible. This includes regulations requiring reporting the use of materials which may pose a health hazard in the

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[20] U.S. Environmental Protection Agency, “About EPA,” available from http://www.epa.gov/epahome/aboutepa.htm; Internet; accessed 15 August 2009.
[21] U.S. Environmental Protection Agency, “Summary of the National Environment Policy Act,” available from http://www.epa.gov/epahome/aboutepa.htm; Internet; accessed 15 August 2009.
[22] 42 U.S.C. §4321 et seq. (1969)
[23] 42 U.S.C. §13101 et seq. (1990)
[24] 29 U.S.C. §651 et seq. (1970)

workplace, as defined by the act. This list contains over one hundred and seventy highly hazardous, toxic and reactive chemicals which require identification, Material Safety Data Sheets and special training in proper handling.[25] "Fulfilling its basic responsibility to control air quality, the EPA was responsible for the elimination asbestos from construction manufacturing.[26]"

From an initial frame-work for constructing safe structures, government regulation of the construction industry has grown to regulate nearly every aspect of the construction process. While the number of laws regulating the construction industry has grown, environmental organizations which comprise part of the green movement continue to push for even tougher regulations and more stringent requirements for the materials which are available for use by the construction industry. Green building is the term used to promote the ideals of environmental groups, today it has gained widespread acceptance and plays an important role in shaping both government regulations and public opinion about construction materials.

2.5 Green Building, the Green Movement and its Influence on Construction

Green building is an offshoot of the Green Movement. Green building is defined by the United States Environmental Protection Agency (EPA) as: "The practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Green building is also known as a sustainable or

[25] U.S. Department of Labor, "List of Highly Hazardous Chemicals, Toxics and Reactives," available from http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=9761&p_table=STANDARDS; Internet; accessed 15 August 2009.
[26] U.S. Environmental Protection Agency, "Asbestos Basic Information," available from http://www.epa.gov/asbestos/pubs/help.html; Internet; accessed 30 August 2009.

high performance building."[27] Green building is not confined to the United States but is an international movement with at least seventeen different countries having their own major green building organizations. International regulations and building codes such as ISO 14001 and ISO 21931[28] have been encouraged by the United Nations as standards for green building. In 2004 the United Nations formed a voluntary initiative known as the Global Compact which encourages companies to follow ten principles for conducting business. Three of the ten principles deal with environmental friendliness.[29]

The Green Movement is an environmental effort started by environmentalists in the 1960's and 1970's. The Green Movement is a powerful political force. Global warming is frequently used as motivation to push the environmental agenda and has far reaching implications for government regulation of construction, manufacturing and the daily life of the average citizen. The increase in the popularity of the concept of global warming has added a sense of urgency to the message of environmentalists. In June of 2009, the U.S. House of Representatives passed a global warming initiative; this action demonstrates the strength of the green movement. If passed into law, the U.S. government will be empowered to further advance tougher construction material requirements of green building and the Green Movement.

Despite the strength of the Green Movement there are signs that public support for increased environmental regulation and its associated costs may slow. Economic downturns seem to diminish public support for the green movement. In January of 2009, a Pew Research

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[27] U.S. Environmental Protection Agency, "Green Building Basic Information," available from www.epa.gov/greenbuilding/pubs/about.htm; Internet; accessed 15 June 2009.
[28] International Organization for Standardization, "Sustainability in Building Construction, 2006," available from http://www.iso.org/iso/catalogue_detail?csnumber=40434; Internet; accessed 24 October 2009.
[29] United Nations Global Compact, "The Ten Principles, 2004," available from http://www.unglobalcompact.org/AboutTheGC/TheTenPrinciples/index.html; Internet; accessed 24 October 2009.

Center Poll showed that global warming came in last among twenty voter concerns, showing that environmental concerns were far behind economic concerns for the majority of citizens.[30]

There are essentially two principles which attract people to green building. The first principle is conservation of resources. It is based on the basic law of scarcity. Energy, in the form of electricity, oil and gas cost money. The more efficiently these resources are used, the more money is saved. It makes economic sense to conserve energy and, therefore, conserve money. Conservation of energy came to the attention of most Americans in modern times with the rise of utility costs and oil shortages in the 1970's. The rise in energy costs produced demand for automobiles and structures that were more efficient. In the 1980's energy costs again fell but energy spikes in recent years have again sparked the interest of the general public in the efficient use of resources. The second principle that attracts people to green building is the environmental movement. People generally want to preserve a healthy and clean planet. While not all people interested in green building consider themselves environmentalists, most people are interested in decreasing pollution and doing their part.

It should be noted that the aims of the environmental movement are sometimes in conflict with the needs of modern life as materials which are commonly used may be deemed environmentally unfriendly, hazardous or toxic by environmentalists. It is not feasible to simply eliminate every material which may be deemed unfriendly. Instead, innovations and more environmentally friendly alternatives which provide equivalent value must be identified for new materials to be readily adopted. Many green practices have a higher initial cost, but produce a cost savings over the life of the product. The use of a photovoltaic or solar power system is a good example of this. The initial cost will be higher but reduced energy bills overtime can

[30] A. Revkin, "Environmental Issues Slide in Poll of Public's Concerns," *The New York Times*, 23 Jan 2009, sec. A13.

produce savings. Many materials or methods that are recognized as green have a higher initial cost as well as a higher lifetime cost. Materials or methods which offer only environmental friendliness are the least likely to be adopted. Often when the environmentally friendly alternative is uncompetitive, environmentalists will seek change through government regulation. Some materials are not environmentally friendly but alternatives do not exist. The lack of alternatives does not guarantee that environmental groups will stop seeking elimination of a material. Environmentalists continue to push for tougher regulation of materials.

In the past, participation in green building has been voluntary and a way for companies to show their environmental friendliness. In the future, it appears that green building may not be an option, it will be the standard. The construction industry will have to adapt to the new regulations, restrictions, material requirements and methods for compliance.

2.6 PVC: A Controversial Chemical

Polyvinyl Chloride (PVC) has been at the center of a fierce political debate for a number of years. Environmentalists claim that it is toxic in numerous ways. Manufacturers claim that it is no more toxic than any other common substance. PVC is a durable, versatile material which is used in a wide variety of applications. First discovered in 1872 by Eugene Baumann, when building upon previous research, he left tubes filled with vinyl chloride in direct sunlight.[31] The result was a white porcelain like material. The material proved hard to work with and sometimes brittle. It was not until 1930 that the B.F. Goodrich tire company and rubber producer was searching for a way to bond rubber to metal that a commercially viable process for the manufacture of PVC was invented. PVC is produced by the polymerization of the monomer

[31] K. Mulder and M. Knot, "PVC plastic: a history of systems development and entrenchment", *Technology in Society*, no. 23 (2001): 267.

vinyl chloride (VCM). PVC is composed of chlorine, which is produced from decomposed salt, and of vinyl which is made from petroleum, most often from natural gas. The raw materials are formed into a resin which is shipped to manufacturing facilities for processing. Depending on the final product a wide range of plasticizers, an additive which makes PVC more flexible and able to be used in clothing or fabrics, or stabilizers, an additive which is used in rigid applications, are added to the PVC resin. The result is a material that is inherently resistant to bacteria, semi water proof and flame retardant. Due to its flexibility and other qualities, including low cost of manufacture, PVC is now found all around us in clothing, flooring, automobile interiors, swim toys and construction materials. In 2008, over thirty four and a half million tons of PVC resin was produced. It has been estimated that between sixty-six and seventy percent of global consumption of PVC is for construction materials.[32] In 2002, forty-five percent of PVC sales were of pipe and conduit.[33] PVC conduit and pipe are essentially the same material with the distinction being their end use. Pipe is used to transport liquids while conduit is used as a pathway for electrical wires or pipes.

Due to concern about the toxic chemicals released when burned, building codes often restrict PVC conduit to below ground applications. Since PVC is buried, concerns about fire are greatly diminished. Nevertheless, the use of PVC conduit is still in danger due to the international push to completely phase out all PVC products. PVC pipe and conduit are used in all types of construction; including civil, industrial, commercial and residential. In 2003, it was estimated that municipal water and sewer systems would acquire eight billion dollars worth of PVC pipe over the next twenty years. This figure did not include the large quantities of pipe and

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[32] E. Linak, *Chemical Economics Handbook*, (SRI Consulting, 2009) available from http://www.sriconsulting.com/CEH/Public/Reports/580.1880/, Internet; accessed 19 September 2009.
[33] E.Linak and K. Yagi, *Polyvinyl Chloride (PVC) Resins: Chemical Economics Handbook Marketing Research Report* (California: SRI International, September, 2003); quoted in F. Ackerman, *Poisoned for Pennies: The Economics of Toxics and Precaution* (Washington DC: Island Press, 2008), 166.

conduit installed in residential, commercial, industrial or agricultural applications.[34] According to industry estimates, PVC accounts for more than seventy percent of all water and sewer pipes being installed in the U.S.[35] It is important to note that not all products recommended for plumbing or sewer use are recognized as suitable alternatives for use as electrical conduit. As electrical conduit, PVC competes primarily with steel. Steel is more expensive, harder to bend and to install, but is often required by code. In underground applications steel must be protected against corrosion. The traditional application for steel in underground use is either PVC Coated Steel or Galvanized Steel. In some areas, such as New York City and Chicago, PVC must be avoided due to building codes. In other areas, the choice of building without the use of PVC is due to interest in green building.

In 2003, Frank Ackerman and Rachel Massey released a study titled, *The Economics of Phasing Out PVC*. The study takes a detailed look at how to phase out PVC and what the economic impacts of this phase out would be. They persuasively argue that because PVC has had a longer history of production and innovation the price of the material has come down. They also argue that there are alternatives to PVC that, if given the chance to compete with PVC will become competitive in price and function. When asked specifically about alternative materials for PVC author Frank Ackermann directed the researcher to contact the Healthy Building Network (HBN) for detailed information. The following sections will examine the debate behind the call for the elimination of PVC.

[34] F. Ackerman and R Massey, *The Economics of Phasing Out PVC*, (Somerville, MA: Tufts University, 2003), 13
[35] K. Christman, "Vinyl Use in Buildings and Construction," *Vinyl Institute* (2003); quoted in F. Ackerman and R Massey, The Economics of Phasing Out PVC, (Somerville, MA: Tufts University, 2003), 13

2.7 Green Building Organizations and Their Call for the Elimination of PVC

2.7.1 Greenpeace

Greenpeace is one of the most widely known environmental organizations in the world. Originally formed in 1971, their vision of a "Green and Peaceful World" has grown to a global environmental organization with a presence in forty-six countries and nearly three million financial supporters.[36] Greenpeace is not specifically an organization that regulates building practices. It describes its self this way: "Greenpeace is an independent global campaigning organization that acts to change attitudes and behavior, to protect and conserve the environment and to promote peace…Creating a toxic free future with safer alternatives to hazardous chemicals in today's products and manufacturing."[37] Starting in 1987, Greenpeace has been campaigning for the phase out of organochlorines. Organochlorines, also known as organocholrides, are defined as organic compounds that contain at least one covalent bond to chlorine. While most organochlorines are pesticides, the production of PVC plastic uses thirty percent of all chlorine manufactured.[38] In part, because of efforts by Greenpeace a large number of organizations have agreed to reduce the use of, or phase out, PVC and Chlorine. Because PVC is used so widely, it is impractical to simply eliminate it. However, this has not stopped Greenpeace from campaigning for the total elimination of PVC.

2.7.2 Bans on PVC

As part of its goal to create a toxic free future, Greenpeace published a paper in August of 2001 titled *PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide*. The

[36] Greenpeace, "The History of Greenpeace," available from http://www.greenpeace.org/international/about/history; Internet; accessed 7 September 2009.
[37] Greenpeace, "Who We Are," available from http://www.greenpeace.org/international/about/our-mission; Internet; accessed 7 September 2009.
[38] Greenpeace, *PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide* (Amsterdam, Netherlands, 2001), 4.

paper described reasons for the elimination of PVC, various laws that have been enacted towards that goal and different municipalities and organizations which have voluntarily phased out PVC. Restrictions on PVC by cities began with the German town of Bielefeld in 1986. By the late 1990's Spain had declared sixty-two cities PVC free. As of 2001, there were two hundred seventy-four communities that had laws restricting the use of PVC. In 2001, the first total ban on PVC was signed into law in Slovakia. This affected all products including packaging and construction materials.[39] Sweden was the first country to propose national restrictions on PVC. In 1995, the Swedish Parliament voted to phase out both soft and rigid PVC. The Swedish Minister for the Environment made the following comment, "The question is not whether to phase out PVC, but how to phase it out." Denmark announced a strategy to reduce PVC in 1999 by introducing a new tax on PVC along with an additional tax on a toxic additive in PVC known as phthalates.[40] Phthalates, also known as phthalic acid is a chemical primarily used as a plasticizer or softener of PVC plastic. In some cases, phthalates have been shown to increase the risk of birth defects and are associated with other health issues for adults and children. One aim identified by Denmark was to limit the incineration of PVC waste. Recycling is common in Denmark; however, PVC is considered difficult to sort out from other waste material and is often incinerated. In places like Japan and Europe incineration is a common practice for waste disposal. Incinerators are often configured to produce electricity and require less land than landfill waste disposal, which is most common in the U.S. Greenpeace claims that through incineration, PVC has the potential to release polychlorinated dibenzodioxins, also known as polyhalogenated chlorines or dioxins, which are environmental pollutants. Additionally,

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[39] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 6.
[40] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 5.

Greenpeace claims that dioxins are also produced during the manufacture of organochlorines including PVC.

2.7.3 International Actions Concerning PVC

International agreements and conventions have set a priority on how to address hazardous substances. Substances which are considered persistent, toxic and bioaccumulative have been targeted. Organohalogens have been specified as a target. Organohalogens are defined as any organic compound which contains at least one halogen. Chlorine is one of five non-metallic element halogens: fluorine, chlorine, bromine, iodine and astatine. Chlorine is a primary ingredient in PVC. Organocholrines meet the definition of organohalogens. Because of the chemistry of PVC, it falls into a category of toxins which are primarily composed of pesticides. In some cases politicians eager to restrict pesticides may unknowingly agree to regulate the production and manufacture of PVC.

In 1992, the United Nations Council on Environment and Development (UNCED) organized the Rio Earth Summit. The summit produced the statement that: "As concerns other sources of pollution, priority actions to be considered by states may include…eliminating the emission or discharge of organohalogen compounds."[41] In 1997, the United Nations Environment Programme Governing Council issued a follow up to the Earth Summit to negotiate a legally binding global convention to reduce and/or eliminate persistent organic pollutants (POP's). Twelve chemicals have been identified as "The Dirty Dozen" which have priority for

[41] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 10.

reduction and where possible elimination. Chlorine, the chief component of PVC has been identified in this list. [42]

In 1992, the North-East Atlantic (OSPAR and North Sea Conference) regulated the use of Chlorine in manufacturing in an effort to reduce chemicals reaching the sea. In 1995, the North Sea Conference produced a definition of toxic or hazardous substances as; "Substances or groups of substances that are toxic, persistent and liable to bioaccumulate." [43] In 1998, the conference produced the following statement "The OSPAR List of Chemicals for Priority Action include several substances which are by-products of the production of chlorine and PVC, or additives in PVC: dioxins and furans, chlorinated paraffin, mercury and organic mercury compounds, lead and organic lead compounds, organic tin compounds and certain phthalates (DBP & DEHP)."[44] Clearly these international agreements identify PVC and its various elements as a target for elimination.

In 1992, the International Joint Commission, USA/Canada, stated that the use of chlorine and its compounds should be avoided in the manufacturing process. "The Commission therefore recommends that the parties, in consultation with industry and other affected interests, develop timetables to sunset the use of chlorine and chlorine containing compounds as industrial feedstocks."[45]

Greenpeace has released the following statement in response to these international agreements. "Greenpeace is campaigning for these agreements to be implemented through a

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[42] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 11.
[43] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 7.
[44] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 8.
[45] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 9.

clean production approach, which targets the substitution of hazardous substances or materials which give rise to hazardous substances such as PVC, as the most effective method of stopping the release of these dangerous substances into the environment." [46]

2.7.4 U.S. Green Building Council and the Leadership in Energy and Environmental and Design Certification

In the United States there is no organization more prominent in green building than the United States Green Building Council (USGBC). The USGBC describes its self in this way: "The Washington, D.C. based U.S. Green Building Council (USGBC) is a 501 c3 non-profit organization committed to a prosperous and sustainable future for our nation through cost-efficient and energy-saving green buildings... With a community comprising 78 local affiliates, more than 20,000 member companies and organizations, and more than 100,000 LEED Accredited Professionals, USGBC is the driving force of an industry that is projected to soar to $60 billion by 2010."[47]

In 1998, the USGBC successfully introduced a scoring system for measuring the environmental friendliness of a building. The Leadership in Energy and Environmental Design Certification (LEED) has grown into the most widely recognized system for measuring green building. The LEED rating system is based on achieving a certain number of points, which are allocated for design choices defined within each standard. The USGBC describes LEED this way: "The Leadership in Energy and Environmental Design Green Building Rating System is a voluntary, consensus-based national rating system for developing high-performance, sustainable buildings. LEED addresses all building types and emphasizes state-of-the-art strategies in five

[46] Greenpeace, PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide (Amsterdam, Netherlands, 2001), 4.

[47] U.S. Green Building Council (USGBC), "About USGBC," available from http://www.usgbc.org/DisplayPage.aspx?CMSPageID=124; Internet; accessed 29 August 2009.

areas: sustainable site development, water savings, energy efficiency, materials and resources selection, and indoor environmental quality."[48]

Four levels of certification exist; Certified, Silver, Gold, and Platinum. Each level is reached by obtaining points from a LEED rating system that offers seven prerequisite points and sixty nine elective points. To achieve any certification a project must comply with the seven prerequisite points, while the elective points determine the LEED rating that a building will receive. A Certified rating is awarded when a building receives between twenty-six and thirty-two points, a Silver rating is awarded when a building receives between thirty-three and thirty-eight points, a Gold rating is awarded when a building receives between thirty-nine and fifty-one points and a Platinum rating is awarded when a building receives between fifty-two and sixty-nine points.

Cost of design, consultation and materials are likely to rise with each level. Owners who desire to have a building LEED certified should be aware of potential cost impacts associated with certification. A 2003 study prepared by Northbridge Environmental Management Consultants found that detailing the cost of LEED certification is extremely difficult since the cost varies greatly due to varying types of construction. However, the study did find that the incremental costs of obtaining certification for public buildings would add at least nine hundred million dollars per year and the figure may be as high as two billion dollars. If all public projects were to comply with LEED, costs would rise an additional four to eleven billion dollars per year.[49] While a number of LEED requirements may produce a reduced consumption of energy which could reduce the lifetime costs of a building. The study concludes that careful analysis

[48] U.S. Green Building Council (USGBC), "About USGBC," available from http://www.usgbc.org/DisplayPage.aspx?CMSPageID=124; Internet; accessed 29 August 2009.
[49] Northbridge Environmental Management Consultants, *Analyzing the Cost of Obtaining LEED Certification* (Westford, MA, 2003), 2.

should be made because "expanding these requirements to additional jurisdictions would raise the cost of these projects and the potential benefits of certification may not justify these costs."[50]

Regional content requirements stipulate that all elements of a material be harvested, manufactured and delivered within a five hundred mile radius of the construction and material must be documented for pre and post consumer recyclable content. LEED also restricts certain materials such as any substances which may emit harmful chemicals or odors; this includes greenhouse gas emissions from manufacture.[51] The regulations on greenhouse gases and emissions from manufacture are important and have the potential to impact use of PVC based upon the claimed emissions of dioxins. In the early development of LEED a credit was proposed for the avoidance of PVC in building products. At this time LEED does not offer points for PVC avoidance but the topic is under review by the USGBC technical advisory committee.[52] It is important to understand the influence of the USGBC and LEED in relation to the elimination of PVC because of the prominent roll that this organization plays. If the USGBC does encourage the elimination of PVC the results could have wide implications.

As of 2003, the government began adopting LEED as a standard for new construction, and many existing buildings were also required to be retrofitted to comply with these requirements.[53] The General Services Administration requires LEED certification for its new buildings; as does the Department of the Navy and Army Corps or Engineers. State governments in New York, Washington, and Oregon have adopted some green building requirements and

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[50] Northbridge Environmental Management Consultants, *Analyzing the Cost of Obtaining LEED Certification* (Westford, MA, 2003),1-2.
[51] U.S. Green Building Council (USGBC), "About USGBC," available from http://leedcasestudies.usgbc.org/materials.cfm?ProjectID=189, Internet; accessed 29 August 2009.
[52] U.S. Green Building Council (USGBC), "USGBC: PVC Task Group Background and History," available from http://www.usgbc.org/displaypage.aspx?CMSPageID=153 Internet; accessed 29 August 2009.
[53] Northbridge Environmental Management Consultants, *Analyzing the Cost of Obtaining LEED Certification* (Westford, MA, 2003),8.

Maryland has officially adopted LEED for all new state construction and renovations larger than seven thousand, five hundred square feet. Other local governments have also adopted LEED including; Los Angeles, San Jose and San Mateo in California; as well as Portland, Oregon and Seattle, Washington. Other states, including; Connecticut, Minnesota and California; as well as cities, including; San Francisco and New York are considering requiring LEED certification for all new construction and renovations.[54] The influence and power of the USGBC is extraordinary for a non-government organization.

2.7.5 Cascadia Region Green Building Council and the Living Building Challenge

The Cascadia Region Green Building Council (CRGBC) was incorporated in 1999. It is one of three original chapters of the USGBC.[55] In 2006, the CRGBC formally announced the Living Building Challenge (LBC). The LBC is an attempt to set a new, higher standard for progression beyond the requirements of LEED, with the object of producing buildings that are sustainable. CRGBC describes the LBC in this way: "The Living Building Challenge is a rigorous performance standard that defines the closest measure of true sustainability in the built environment, using a benchmark of what is currently possible and given the best knowledge available today. Version 1.3 is comprised of sixteen prerequisites within six performance areas, or Petals: Site, Energy, Materials, Water, Indoor Quality, Beauty and Inspiration."[56]

The LBC has the goal of producing buildings that can operate independently of outside resources provided through civil services such as power, electricity and sewage. The LBC

[54] Northbridge Environmental Management Consultants, *Analyzing the Cost of Obtaining LEED Certification* (Westford, MA, 2003), 1.
[55] Cascadia Region Green Building Council (CRGBC), "About Cascadia Region Green Building Council," available from http://www.cascadiagbc.org/about-us; Internet; accessed 29 August 2009.
[56] Cascadia Region Green Building Council (CRGBC), "About Cascadia Region Green Building Council," available from http://www.cascadiagbc.org/about-us; Internet; accessed 29 August 2009.

system is different than LEED. Rather than awarding points based upon meeting requirements the LBC requires developers to meet sixteen prerequisites based upon principles. These principles include: responsible site selection, limits to growth, habitat exchange, net zero energy, materials red list, carbon footprint, responsible industry, appropriate materials radius, construction waste, net zero water, sustainable water discharge, civilized work, source control, ventilation, design for spirit, and an inspirational and educational environment.[57] The standard of the LBC is so rigorous that as of 2009, there was no single structure in the world that has been certified as a Living Building. In 2009, the CRGBC authorized a study that was conducted through a collaboration of companies including; the New Buildings Institute, Sera Architects, Gerding Edlen, Interface Engineering and Skanska USA Building. The study examined the potential to meet the sixteen prerequisites for seven different building types in four different climates of major cities. Using LEED Gold or Platinum certification as a base line, it identified what additional costs might be incurred. The study is currently under peer review.

One area of potential impact of the LBC is the material requirements which prohibit the use of certain materials which are believed to be toxic to human health in their use, manufacture or disposal. These material requirements are know as the materials red list. The Materials Red List is a list of materials, or chemicals found in materials, that are not to be used in the construction process. PVC is the most commonly used construction material on the materials red list.[58] By identifying PVC as a red list material the CRGBC has made clear that it sees the future of construction and green building as a PVC-free environment. When CRGBC was approached

[57] Cascadia Region Green Building Council (CRGBC), "About Cascadia Region Green Building Council," available from http://www.cascadiagbc.org/about-us; Internet; accessed 29 August 2009.
[58] Cascadia Region Green Building Council (CRGBC), "About Cascadia Region Green Building Council," available from http://www.cascadiagbc.org/about-us; Internet; accessed 29 August 2009.

about which alternatives to use instead of PVC, they recommended contacting the Healthy Building Network for specific materials.

2.7.6 Healthy Building Network

The Healthy Building Network (HBN) is another organization that advocates the complete elimination of PVC. The HBN was established in 2000, by members of the national environmental health movement. The HBN take a proactive approach. Rather than simply fighting for the elimination of PVC and other materials that it feels are not environmentally friendly, the HBN focuses on "the introduction of new, healthier building materials into commercial markets, shifting over $4 billion in material purchases from toxic materials to healthier alternatives that are comparable in both price and performance to the materials they have replaced."[59] The HBN has played a key role in setting green building guidelines and has produced the first on-line evaluation tool for building materials. Rather than seeking to implement its agenda solely through government regulation, the HBN has developed a consumer-driven system for evaluation of green building materials, called "Pharos". The HBN hopes that Pharos will become the leading materials evaluation tool used by green building and procurement professionals. The HBN website states that "Through informed specification and selection of building materials, we can measurably enhance the environment, human health and social benefits associated with the contemporary building industry."[60] Pharos is designed to be used by the architect, designer or other decision maker seeking to use green materials. The goal is to introduce and incorporate these materials into the construction process through education

[59] Healthy Building Network, "About Us," available from http://www.healthybuilding.net/about/index.html; Internet; accessed 16 September 2009.
[60] Pharos Project Home, "The Pharos Project," available from http://www.pharoslens.net/; Internet; accessed 16 September 2009.

about available alternatives and voluntary adoption. Because of this consumer driven approach, the HBN has developed a comprehensive list of environmentally friendly alternative materials, including several for PVC conduit. The alternatives identified by the HBN for the replacement of PVC electrical conduit are included in this study and discussed below.

2.8 Alternatives to PVC Conduit

Because there are many uses of PVC, there are many alternatives for each application; this research does not attempt to study all the alternatives for each application or to perform a detailed examination of the chemical properties or environmental friendliness of each alternative material. As noted before, around seventy percent of all PVC is used in construction and the majority of PVC for construction use is pipe and conduit.[61] For this reason, this study focused on the use of PVC conduit and its alternatives. As the Healthy Building Network was the most commonly cited source for PVC alternatives, this study has focused on the materials identified by the HBN. Descriptions of these alternatives are found below.

2.8.1 High Density Polyethylene

High density polyethylene (HDPE) is available for all pipe applications and is non-chlorinated, requires fewer additives and is more easily recycled. It is considered more environmentally friendly as well. HDPE is less resistant to combustion than PVC, but smolders at a higher temperature. HDPE does not release hydrochloric acid before combustion. Of all alternative materials, HDPE has seen the most growth in the conduit sector and is competitive with PVC in cost. HDPE also comes in rolls of several hundred feet making it useful for

[61] F. Ackerman, *Poisoned for Pennies: The Economics of Toxics and Precaution* (Washington DC: Island Press, 2008), 166.

covering long distances such as in civil construction, while PVC typically comes in twenty foot sections.[62]

2.8.2 Polypropylene

Polypropylene (PP) is made from the monomer propylene and shares many of the strengths of PVC. It is chemical resistant, flame retardant and light weight. This pipe is useful for industrial applications involving corrosive media. PP may be used at temperatures up to one hundred and fifty degrees Fahrenheit, in continuous pressure and at temperatures up to one hundred and eighty degrees Fahrenheit, within gravity flow conditions. PP is also the lightest of all thermoplastics and has good resistance to strong acids, except highly active oxidizers, such as nitric acid. It also has excellent resistance to weak and strong alkalis and to most organic solvents. PP is also a non-conductor of electricity.[63] PP pipe or conduit is typically available in diameters up to four inches and twenty feet in length.

2.8.3 Galvanized Steel

Galvanized steel is a created by coating traditional steel with zinc which provides a resistance to corrosive environments and rust. Galvanized steel conduit is more suited to underground use than traditional steel. Galvanized steel is a much heavier material than plastics and despite its corrosion protection does not appear to stand up to chemical environments as well as plastics. Galvanized steel is found almost as commonly as PVC conduit in construction despite higher cost and weight.

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[62] J Harvie and T Lent, "PVC-Free Pipe Purchasers' Report," (Healthy Building Network, 2002), 14.
[63] Industrial Plastic Pipe, "Polypropylene Pipe," available from http://www.industrialplasticpipe.com/pages/PolypropylenePipe.htm; Internet; accessed 16 September 2009.

2.8.4 Fiberglass

Fiberglass was invented in 1938 and consists of glass fibers combined with a polymer resin which results in a high strength, low weight product. Product sales materials claim a weight reduction of fifty-five percent over PVC. It is available in diameters up to four inches and up to twenty feet in length. Because of the strength of the fiberglass material it may be buried directly without concrete encasement.

2.8.5 Fiberglass Reinforced Epoxy

Fiberglass Reinforced Epoxy (FRE), also known as glass reinforced epoxy pipe is similar to fiberglass pipe but uses a plastic product instead of resin. This pipe is commonly used in marine settings and is available in diameters up to forty inches and up to forty feet in length.

2.8.6 Nylon

Nylon pipe or conduit is a product commonly used in plumbing and fittings, and is available at local hardware stores. While Nylon does not have the flame retardant properties of PVC, it is a low smoke product. Nylon is most commonly found as the pipe product called, Liquid Tight Conduit. For underground applications Liquid Tight is often found in the form of a corrugated flexible steel conduit coated with Nylon for corrosion protection. Liquid Tight is only rated for direct burial or concrete encasement and is available in diameters up to one inch and in rolls of several hundred feet.

2.8.7 Polyurethane Coated Steel

Polyurethane Coated Steel is steel that has been coated with polyurethane for chemical resistance. Polyurethane can also be found in the form of tubing used for a number of applications, but it does not have the strength required to withstand the load of direct burial or concrete encasement. When steel is coated with polyurethane the two materials compliment each other to provide strength and chemical resistance. The steel may be coated before or after installation, making it available for use in any size of steel.

This list of materials, discussed above, comes from a list of alternatives to PVC for electrical conduit as described by the HBN. It is beyond the scope of this study to determine if these products are more environmentally friendly than PVC. The PVC industry has argued many times that if other materials were subjected to the same scrutiny as PVC, it could be revealed that PVC is the most viable option.

2.9 Summary

As shown through the review of literature, there is a fierce campaign to eliminate PVC. However, even the harshest critics admit that it plays a valuable role in our society and that replacing it is not easy. The price, convenience and adaptability of PVC make it a difficult material to replace. PVC is an interesting polymer because it can accept a much wider range of additives than other plastics. Many of the criticisms stem from its association with chlorine. It has been argued by some that this association is inherently unsustainable; however, it appears that much of this argument has been based on emotion rather than on scientific scrutiny.[64]

[64] J. Leadbitter, "PVC and Sustainability," *Progress in Polymer Science*, no. 27 (2002): 2197.

Greenpeace in particular would like to see the end of all chlorine chemistry. The use of chlorine as a primary element in PVC is one of the strongest arguments that Greenpeace has used to push for the elimination of PVC. Some of their arguments have merit, as the industry associated with the use of chlorine in manufacturing has not always been careful in its practices. Despite improvements in modern manufacturing the industry retains a tarnished reputation. Not withstanding the reputation of chlorine and its users, it should be acknowledged that chlorine has many benefits. For example, over eighty percent of all pharmaceutical products are derived from chlorine chemistry, and the addition of chlorine in drinking water prevents disease through the destruction of harmful bacteria.[65] The presence of chlorine gives PVC a unique range of technical features that has given the product much strength in making it such a useful product.

Greenpeace has focused on the complete elimination of chlorine and PVC rather than allowing producers to improve the manufacturing process and reduce emissions. In 1997, a network of English universities known as the National Centre for Business and Ecology conducted a study titled “PVC in Packaging and Construction Materials –an assessment of their impact on human health and the environment.” This report took a critical look at the PVC industry and indicated that there were several areas that needed to be cleaned up; but if these areas were modified, then PVC production could become environmentally acceptable. The report stated that “The study team was unable to find conclusive scientific evidence linking the production, use or disposal of PVC compounds where best industry practice is utilized, to substantial harm to human health.”[66] This report recognized that there were areas for improvement, but clearly stated that the process could be managed, instead of simply eliminated. Rather than accept the findings of this report Greenpeace has continued to campaign against

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[65] J. Leadbitter, “PVC and Sustainability,” *Progress in Polymer Science*, no. 27 (2002): 2200.
[66] J. Leadbitter, “PVC and Sustainability,” *Progress in Polymer Science*, no. 27 (2002): 2204.

PVC and chlorine, often referring to it as “the Devil’s element.”[67] Others have followed suite, an internet search of PVC will yield results such as “PVC: The poison plastic”, author Frank Ackerman published a book titled “Poisoned for Pennies: the Economics of Toxics and Precaution,” which dedicates a chapter to the evils of PVC, while The World Watch Institute released a paper titled “Why Poison Ourselves: A precautionary Approach to Synthetic Chemicals examines the environmental impacts of PVC.” Clearly, the debate about the environmental and health impacts of PVC has not been settled. What has been established is that PVC is a versatile and dynamic material with a wide variety of uses. Manufacturers of PVC have acknowledged concerns and have worked to improve manufacturing techniques. Even the harshest critics of PVC acknowledge that in many areas a competitive alternative has not been identified.

It has not yet been decided if PVC will eventually be eliminated through government regulation or replaced by another product; due to concerns of purchasers or because of innovation of superior products. However, the possibility of elimination is real and there is a need to identify alternatives best able to replace this versatile yet controversial material.

The next chapter will discuss the methodology used in this study for evaluating the awareness and preference of electricians in the state to Utah for alternative underground conduit, as identified by the Healthy Building Network.

[67] J. Leadbitter, “PVC and Sustainability,” *Progress in Polymer Science*, no. 27 (2002): 2200.

METHODOLOGY

3.1 Gathering Background Information

A review of literature was conducted and showed that PVC, a common construction material, has been targeted by a number of environmental groups for elimination. The review of literature also found that in 2008 around seventy percent of PVC produced was used for construction and that over forty percent of this PVC was used for pipe or conduit.[68] PVC pipe and conduit are essentially the same material but are differentiated by their end use. Pipe is typically used for the distribution of liquids, while conduit is primarily used as a pathway for electrical cables. PVC conduit is widely used in civil, industrial and commercial construction. This study focused on electricians working for major electrical contractors involved with commercial construction in the state of Utah in order to determine their awareness and preference of environmentally friendly alternatives if PVC conduit were eliminated. These alternatives were identified by the Healthy Building Network, as described in the review of literature.

For the purpose of this research, major electrical contractors involved with commercial construction were defined as electrical contractors with over one hundred electricians and significant commercial construction experience in the state of Utah. Significant commercial construction experience is defined as experience on one or more projects with a project value of

[68] E. Linak, Chemical Economics Handbook, (SRI Consulting, 2009) available from http://www.sriconsulting.com/CEH/Public/Reports/580.1880/, Internet accessed 19 September 2009.

five million dollars or higher. Although this study focuses on major commercial electrical contractors these same electricians are likely to be involved with industrial and civil construction as well. Major electrical contractors involved with commercial construction are often significant consumers of PVC conduit, in some cases installing miles of conduit on a single project. While small electrical contractors may employ more total electricians, an internet search identified one thousand two hundred and seventy-two electrical contractors in Utah, major electrical contractors with commercial experience are more likely to be significant consumers of PVC conduit. For example, in 2009 one major electrical contractor installed over forty-five miles of PVC conduit in a two hundred and fifty thousand square foot data center constructed in South Jordan, Utah.

Figure 3.1.1: Underground Conduit in Data Center Construction

Figure 3.1.2: Underground PVC Conduit in Data Center Construction

Smaller projects such as residential home construction are less likely to require large amounts of PVC conduit. Because smaller contractors generally use less PVC, they are less likely to have extensive experience with PVC or its alternatives.

For the purposes of this research it was assumed that electricians who meet the qualifications listed may also have experience with at least one alternative material that has been identified as environmentally friendly by the Healthy Building Network. For example, Galvanized Steel, commonly refereed to as GRC or Galvanized Rigid Conduit, is a common material found on the list of alternatives. Because these electricians have experience with a variety of materials, their preferences provide valuable insights into the possible impacts of using various alternative materials.

To locate the population of interest, industry professionals were interviewed to identify the largest electrical contractors in the state of Utah. To further identify possible candidates for this research, a list of electricians from the Associated General Contractors of Utah (AGC of

Utah) was obtained.[69] These preliminary searches identified five contractors who were most likely to meet the research criteria. These contractors were then contacted to verify that they met the definition of major electrical contractor involved in commercial construction in the state of Utah. One of the contractors did not meet the research criteria and the list was shortened to four. Each of the four remaining organizations agreed to allow their electricians to participate in the study. Because of the small population of electrical contractors meeting the research criteria, an effort was made to sample the entire population, one thousand seven hundred and twenty electricians, by distributing questionnaires to all electricians employed by the four major electrical contractors. Individuals in each organization agreed to help in the distribution of the survey instrument.

3.2 Research Design

The research design consisted of creating, testing, administering and analyzing the findings of a multi-item survey instrument. It was decided that a questionnaire would be the most appropriate survey instrument to accurately assess the population base.

The questionnaire was developed following a careful review of literature and with the help of experienced professionals working in the electrical industry. The questionnaire was also reviewed by faculty members at Brigham Young University; Dr. Jay Newitt, Dr. Jay Christofferson, and Dr. Kevin Burr of the Construction Management program and Emeritus Professor, Dr. Ray Andrus of the Marriott School of Management participated in the review and development of the questionnaire. The questionnaire was designed to yield enough information

[69] The Associated General Contractors of Utah, "Member Directory," available from http://www.agc-utah.org/directory.html#bf_dirFrame_598; Internet; accessed 24 August 2009

to assess the experience, role and opinions of each respondent concerning PVC conduit and alternative types of underground conduit.

For the purposes of this research it became apparent that the questionnaire should address several key areas. Among these were the qualifications of the respondents to the questionnaire, their experience with the various types of conduit, preference for each type of conduit, perceptions of cost, and perceptions of ease of installation. The review of literature identified the Healthy Building Network as a respected and often referenced authority of green building. As documented in the review of literature, the Healthy Building Network produced a list of alternatives by construction specification division. Under the electrical division seven alternative materials were identified as environmentally friendly alternatives of PVC conduit. Larry Gruver, Senior Project manager with over forty years of experience of Rosendin Electric, a major national electrical contractor, also reviewed the list of materials to verify that they were viable alternatives to PVC.

3.3 Questionnaire Development

One major concern in the development of the questionnaire was to minimize the time required to take the survey while yielding the maximum amount of information. It was anticipated that participation would be asked of electricians during a morning or lunch break, and that participants would have limited time or interest in participating in a complicated or lengthy survey. With this in mind, the questionnaire was designed to fit a one-half page format that included the introduction, statement of purpose, all research questions and the statement of certification by the University Review Board.

A preliminary questionnaire was produced and distributed to a test group of seven electricians working on a local job site, to help determine the quality of information that could be gained from each question, to get suggestions on how the questionnaire could be improved for clear communication, and to help anticipate evaluation procedures. Based upon the findings of the preliminary questionnaire, a revision was made and redistributed to another seven electricians. With these results, the format was again refined. A meeting of the full research committee was held in which the committee members offered suggestions for further refinement and additional points of interest. With the addition of these changes, the committee gave its approval and the questionnaire was submitted to and approved by Brigham Young University's Institutional Review Board for Human Subjects to ensure that the survey would not harm participants and would pose them minimal risk, if any. Each survey included information for contacting the Brigham Young University Institutional Review Board, should participants wish to do so.[70]

3.4 The Final Survey Instrument

The final questionnaire had nine questions and fifty-one data fields. The questions included information about the respondent, a matrix of the electrician's preferences, yes or no, fill-in-the-blank, and open ended questions so that the method of response would most effectively match the individual question. The questionnaire addressed, in order, the following topics.

Question 1: Open ended question to identify years of experience as an electrician.

Question 2: A matrix which allowed the respondent to indicate strength of feelings about the various types of conduit based upon experience using each type.

[70] Please see Appendix E for Letter of Approval from the Institutional Review Board.

Preference, ease of installation, and cost were rated on a one to five scale. Additionally, two blank areas were left for the respondent to suggest any other type of underground conduit that might be preferred.

Question 3: Fill-in-the-blank question asking respondents to list their top two preferred alternatives.

Question 4: Yes or No question asking respondents about the merit of eliminating PVC conduit to receive a green certification.

Question 5: Open ended question asking respondents to identify concerns about using PVC.

Question 6: Open ended question to share opinion about the possible elimination of PVC conduit.

Question 7: Open ended classification question to identify the respondent's employer.

Question 8: Open ended classification question to identify the respondent's position.

Question 9: Yes or No classification question to identify if the respondent makes purchasing decisions for the company.

Survey participants were guaranteed anonymity as well as access to the findings of the study should the participants request them. The survey also included the author's contact information and a method for contacting Brigham Young University's Institutional Review Board. (To view the questionnaire please see appendix A)

3.5 Survey Distribution

The population of interest was comprised of electricians working for major electrical contractors, involved with commercial construction in the state of Utah, employing more than one hundred electricians. Individuals working for each of the four major electrical contractors agreed to help in the distribution of the questionnaire to electricians working at various projects. For ease of distribution the questionnaire was designed to be printed on a standard eight by eleven inch sheet of paper, with two questionnaires on each sheet. In this way reproduction costs were minimized while maximizing the use of paper. Physical copies of the questionnaire were offered to each volunteer, but in some cases an electronic copy was sent and the volunteer printed and distributed the survey. The response rate varied by organization and appears to have been influenced by the willingness of the volunteer to distribute the questionnaire. Questionnaires were distributed throughout the week of September 14th, 2009. Follow-up calls and personal contact continued until September 25th, 2009 when it was concluded that additional completed questionnaires would not be returned.

3.6 Response Rate

In order to identify the size of the specific study population it was necessary to determine the number of electricians in each company, which met the required definition of major electrical contractor involved with commercial construction in the state of Utah. By definition in this study, the electrical contractor was required to have at least one hundred electricians. A table identifying the four electrical contractors, with the number of electricians and actual response rate for each is found below. It is important to note that the questionnaire was made available to the entire population of electricians in the state of Utah meeting the specified requirements. The target population totaled of one thousand seven hundred twenty electricians; from that population one hundred twelve electricians responded to the questionnaire representing six and a half percent of the total population. (See Table 3.6.1)

Table 3.6.1: Percentage of Population Surveyed

	Reported # of Electricians	Actual Responses	Percentage of Total Population
Cache Valley Electric	1000	67	6.7%
Hunt Electric	270	31	11.5%
Rydalch Electric	100	9	9.0%
Wasatch Electric	350	5	1.4%
Totals	1720	112	6.5%

3.7 Data Entry and Analysis

As the responses were returned, each was individually numbered and manually entered into Microsoft Excel for tabulation and summarization. Microsoft Excel is a commonly used spreadsheet program which provides a wide range of capabilities for analyzing and charting data. Some of the tools used most often were simple mathematical equations to find averages of the scoring as well as cross-tabulation and charts of the data. Findings were analyzed to determine trends and the strength of responses. During the analysis of the findings it was determined that the resulting scores for the strength of preference, ease of installation and cost of material did not communicate well using the one to five scale, with one being the positive response. Due to this flaw in the questionnaire, the values were reversed to show five being the positive response. This resulted in giving positive responses the highest scores and negative responses the lowest scores. The findings of the data analysis are discussed in detail in the next chapter.

DATA ANALYSIS AND FINDINGS

4.1 Introduction

To determine the awareness and perceptions regarding PVC, its alternatives and possible effects of pressures from environmental groups for its elimination, a survey of experienced professional electricians was conducted, as an important part of the larger study of the alternatives to PVC conduit. A hand delivered questionnaire (Appendix A), requiring a penciled response, generated one hundred and twelve valid completed survey documents, representing approximately six and a half percent of the targeted total population. Respondents had a range of less than one year to fifty years of professional experience, with a median experience level of about fourteen and one-half years. Fifty-five percent had over eleven years of experience. The largest group, forty-one percent of respondents, was journeyman electricians. Twenty-four percent were foreman or project managers. Nine percent of respondents reported that they made materials purchasing decisions.

Experience, familiarity and perceptions of alternative conduit materials were determined through use of a matrix question, asking respondents to rate, on a one to five scale, their experience and opinions regarding PVC and other underground conduit materials. Most had experience with several different materials. PVC had been used by eighty-nine percent of the sample, followed by eighty-two percent for Galvanized Steel and lesser amounts for the other six alternatives listed. PVC was clearly preferred and perceived as the easiest to use and least costly. Two-thirds of the respondents reported no concerns about using PVC. Twenty percent reported concerns about the strength of PVC and eleven percent disliked the glue fumes.

The possible elimination of PVC elicited seventy-five written, often emotional, comments. Most were concerned about the increased cost of projects and several gave negative comments about environmentalists. Only one response said that "It would be great for a greener planet." The majority, seventy-six percent, did not feel that green certification justified elimination of PVC conduit. There was also a general sense that PVC probably would not be eliminated. Clearly, sampled electricians are not in agreement with environmentalists' concerns regarding PVC underground conduit. A detailed discussion of these findings follows.

4.2 Profile of the Respondents

In order to understand the profile of the respondents a number of questions were asked concerning their experience as electricians, their opinions on the elimination of PVC conduit for underground applications and the recommended alternative materials.

4.2.1 Years of Experience as an Electrician

Survey respondents were presently employed by a major electrical contractor in the state of Utah, as defined in the research. Respondents had an average of fourteen and one-half years of experience as electricians. There was a wide range of responses to this question ranging from less than one year to fifty years of experience. Forty-five percent of respondents had one to ten years of experience as electricians, thirty-four percent had eleven to twenty years of and twenty-four percent had twenty-one or more years of experience as an electrician. (See Figure 4.2.1)

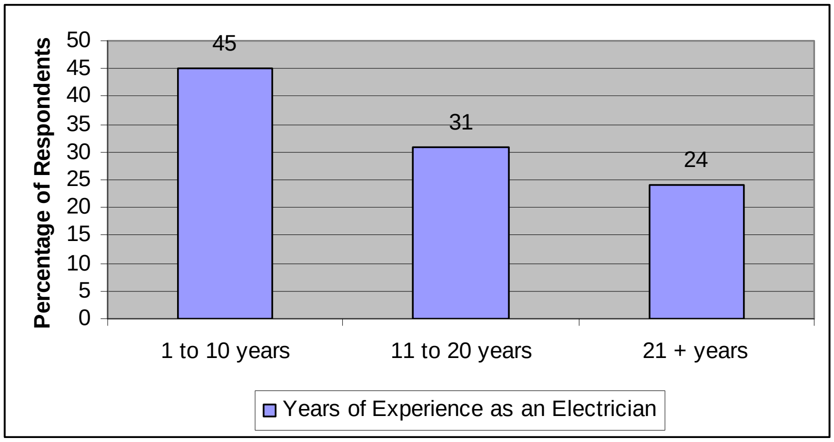

Figure 4.2.1: Respondent's Years of Experience as an Electrician

4.2.2 Current Position Occupied by Each Respondent

Respondents to the survey held a variety of positions in each company. Responses included; Apprentice, Junior Electrician, Journeyman Electrician, Foreman, Superintendent, Project Manager, and Estimator. Of the survey respondents, forty-one percent were Journeymen Electricians, twenty-three percent were Apprentices, fifteen percent were Foremen and nine percent were Project Managers. Three percent answered "Other" which included; Quality Control, Estimator and Superintendent. Nine percent did not respond. (See Figure 4.2.2)

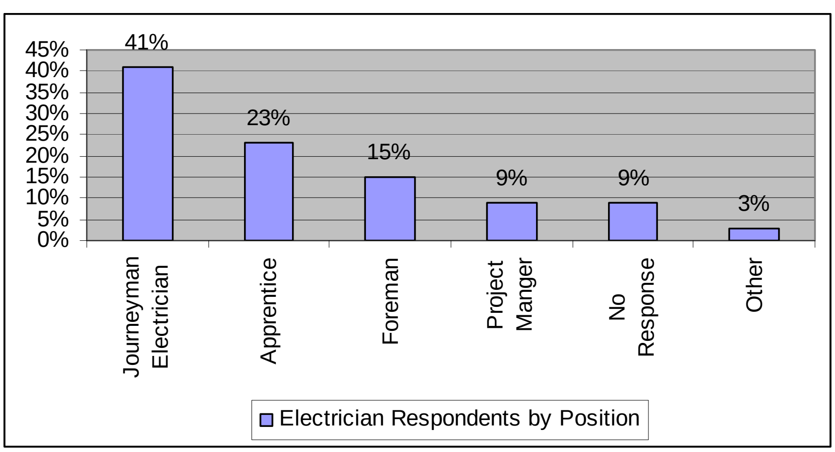

Figure 4.2.2: Position Occupied by Each Respondent

4.2.3 Respondents Who Make Purchasing Decisions

Respondents were asked if they made purchasing decisions for their company. Nine percent responded "Yes," they do make purchasing decisions, while seventy-six percent responded "No," they do not make purchasing decisions and sixteen percent left the question blank. (See figure 4.2.3) The majority of the respondents to this survey do not see themselves as making purchasing decisions.

It is important to understand, that in the construction process, the type of material specified for use is often specified by the designer or architect/ engineer on a project. Even those who make purchasing decisions for these electrical contractors will not often have the ability to choose the type of materials used. However, it is common practice to allow a subcontractor to make a substitution request for an alternative material. If the electricians are aware of another material that provides more value they may have a great deal of influence in introducing a new product to the market because of their specialty and experience; they may persuade a designer to try a new or alternative material. Even though the majority of respondents stated that they do not make purchasing decisions for their company, their insight is still valuable and may affect the adoption of alternative materials.

Because most of the respondents do not make material purchasing decisions they may not have direct knowledge about the cost of conduit materials. However, their experience and opinions of the materials in this study provide insight into the ease of installation which influences productivity and has an effect on the final cost of the project.

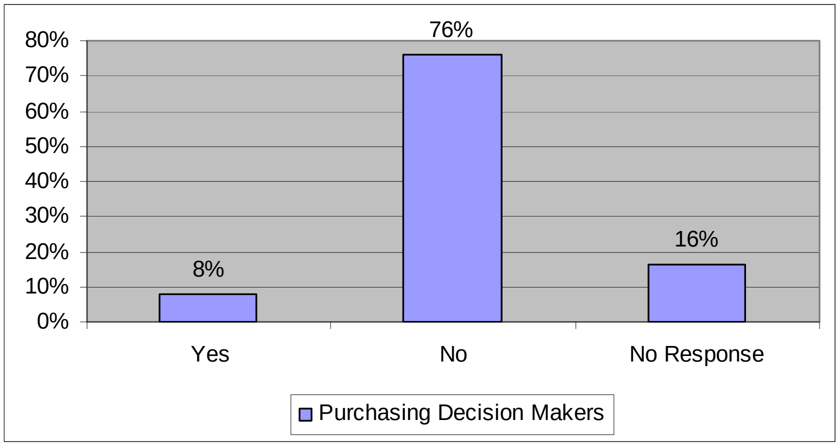

Figure 4.2.3: Percentage of Respondents who Make Purchasing Decisions

4.3 Material Use, Preference, Ease of Installation and Cost

As described in the study design, a matrix question was developed which gave respondents the opportunity to indicate if they had used a material and to rate each conduit material on the basis of their preference, the ease of installation and cost of the material. Below is an analysis of the opinions offered by respondents. Survey respondents were asked to rate each material by preference on a scale of one to five, with one being their favorite and five being their least favorite. During the analysis of the data it was determined that the scale did not effectively communicate the preferences of the respondents. After the data was entered into a Microsoft Excel spreadsheet, a formula was devised to invert response values. For analysis purposes; preference, ease of installation and cost ratings were restated on a one to five scale, with five being the most positive response. A high rating for cost indicates that the response is positive, or in other words, the material is least costly.

4.3.1 Respondents Who Have Used Each Material

The questionnaire included a check box by each conduit material where the respondent indicated which materials they had used. Eighty-nine percent had used Polyvinyl Chloride (PVC); eighty-two percent had used Galvanized Steel (Galv); sixty-three percent had used Polyurethane Coated Steel (PCS); sixty-two percent had used Nylon; forty-five percent had used Fiberglass (Fiber); twenty-nine percent had used Fiberglass Reinforced Epoxy (FRE), twenty-four percent had used High Density Polyethylene (HDPE) and seventeen percent had used Polypropylene (Poly). Many respondents offered opinions about specific materials while not indicating that they had used any of the materials. On the average, there were 9.7 percent more opinions regarding each material than there were respondents who indicated that they had used the material. (See figure 4.3.1) Two factors may explain this discrepancy: first, in many cases it appears the respondents had misread the questionnaire and did not indicate that they had used a material when, in fact, they had; second, some of the respondents may have offered opinions about materials they had not used. Because it is difficult to determine which of these might be the case, for the purposes of this study, the above percentages are based upon those respondents who indicated that they had used a material and not those who offered an opinion. However, it is important to note that the materials may have been more commonly used than the percentages given above. Figure 4.3.1, found below, shows "Responses" which include the total number of respondents who indicated that they had used a material and those who offered opinions; and "Respondents who have Used Each Material" which includes only those who indicated that they had used each material.

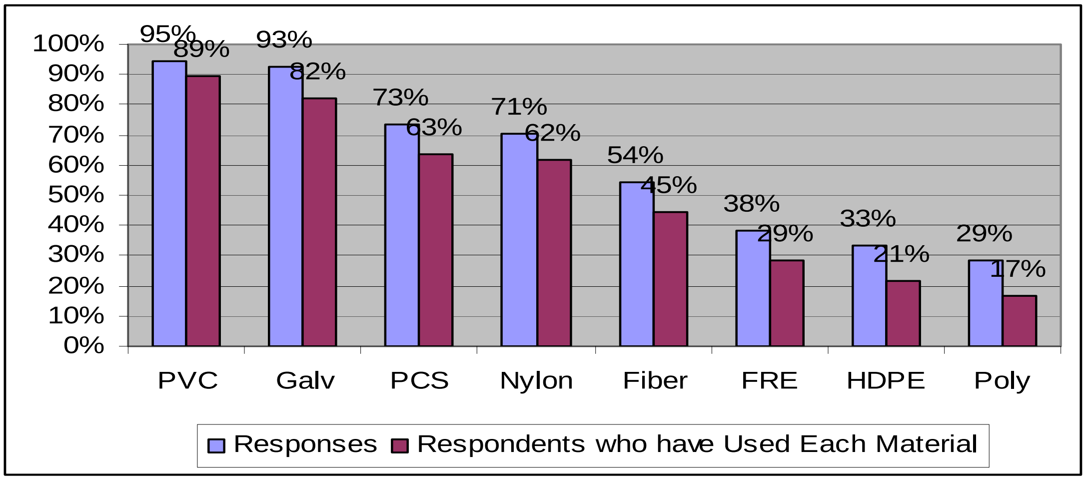

Figure 4.3.1: Percentage of Respondents who have Used Each Conduit Material

4.3.2 Respondents Stated Preference of Each Material

Survey respondents were asked to rate preferences for conduit materials. This is an important figure; however, it does not give a complete picture of the perceived value of each material by the respondents. For this reason this figure is referred to as the "Stated Preference." A more complete picture of the perceived value of each material is found below and is referred to as the "Overall Preference."

Using the one to five scale, with five being positive, the conduit materials received the following scores regarding the respondents stated preference. PVC received the highest average score of 4.49. The next highest average score was for Polypropylene at 3.19; High Density Polyethylene was third with 3.10, Nylon was fourth with 3.00, Galvanized Steel was fifth with 2.70, Fiberglass was sixth with 2.50, Fiberglass Reinforced Epoxy was seventh with 2.22 and Polyurethane Coated Steel was eight with 2.20. (See figure 4.3.2) The total range of the means was 2.29, but if PVC were eliminated the range of the means would only be 0.99; indicating that all other conduit materials were closely grouped together in terms of stated preference.

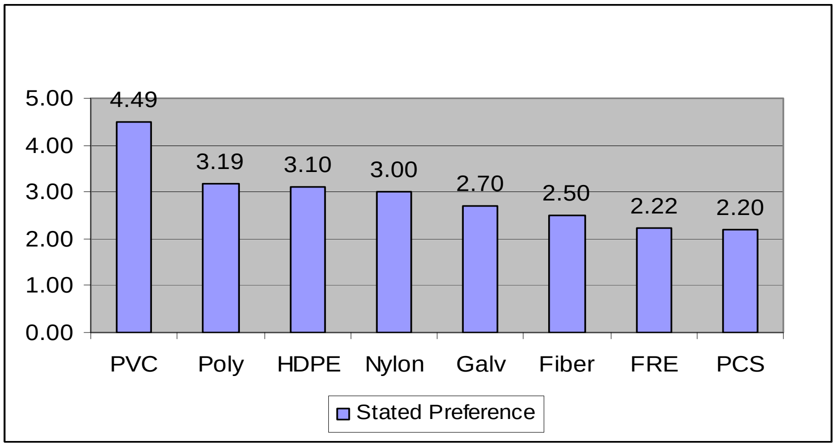

Figure 4.3.2: Stated Preference of Conduit Materials

4.3.3 Ease of Installation

Respondents were asked to rate their perception of each material's ease of installation. Ease of installation is important in determining the value or perceived value of alternative conduit materials by the survey respondents. Ease of installation has the potential to affect the preference for a material; it may also affect the rate of installation and productivity for specific materials. There are several factors that may affect the ease of installation; including the weight of the material, the type of joints required the ability to form or bend the material and the difficulty of repair, if needed.

Using the one to five scale, with five being positive, the conduit materials received the following scores. PVC received the highest average score of 4.72. The next highest average score was for Polypropylene with 3.76, High Density Polyethylene was third with 3.38, Nylon was fourth with 3.24, Fiberglass was fifth with 2.59, Fiberglass Reinforced Epoxy was sixth with 2.46, Galvanized Steel was seventh with 2.42, and Polyurethane Coated Steel was eighth with 2.00. The most notable difference between ratings for Stated Preference and Ease of Installation is that Galvanized Steel dropped from the fifth highest rating to the seventh. The two steel based materials were rated last for ease of installation. (See figure 4.3.3)

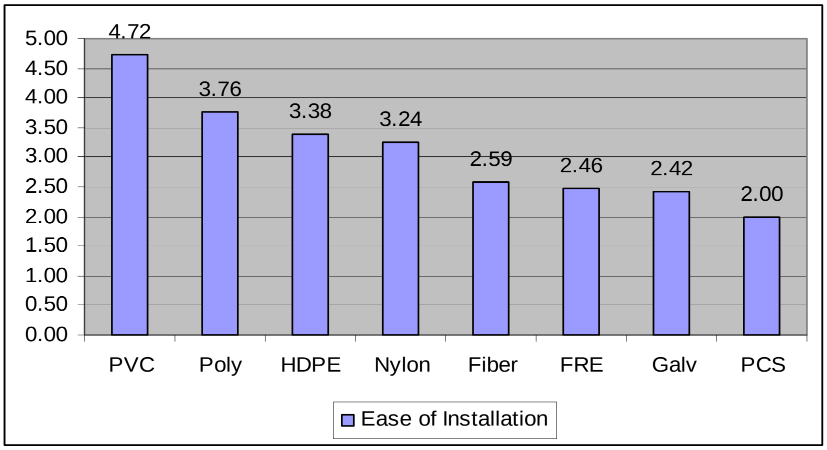

Figure 4.3.3: Ease of Installation of Conduit Materials

4.3.4 Cost of Materials

Respondents were asked to rate each material based upon cost. There are several factors that may be included in cost; including the cost of the material and the cost of labor. The questionnaire did not clarify the difference between the two. Respondents were simply asked to rate their perception of the cost of each material on a scale of one to five, with five being the most positive response or the lowest cost.

PVC was perceived as the least costly material and received the highest average score of 4.76, a 1.82 margin over the next material. The next highest average score was for Polypropylene with 2.94, High Density Polyethylene was third with 2.86, Nylon was fourth with 2.50, Fiberglass was fifth with 2.21, Fiberglass Reinforced Epoxy was sixth with 2.10, Galvanized Steel was seventh with 2.04 and Polyurethane Coated Steel was eighth with 1.39. PVC received its highest rating for its low cost while all other materials received their lowest ratings. The order of preference remained the same compared to ease of installation. The total range of the means was 3.21 and was the largest difference of any of the surveyed areas. (See figure 4.3.4)

Increased cost of material does not appear to add value to the respondents. In fact, the least costly materials were also rated as the easiest to install. The one exception was Galvanized Steel, which was ranked as fifth in Stated Preference, but seventh in both Ease of Installation and Cost. Many of the respondents expressed concerns that by replacing PVC with an alternative material that prices would raise, resulting in higher project costs; which may result in smaller and fewer projects, impacting their personal employment.

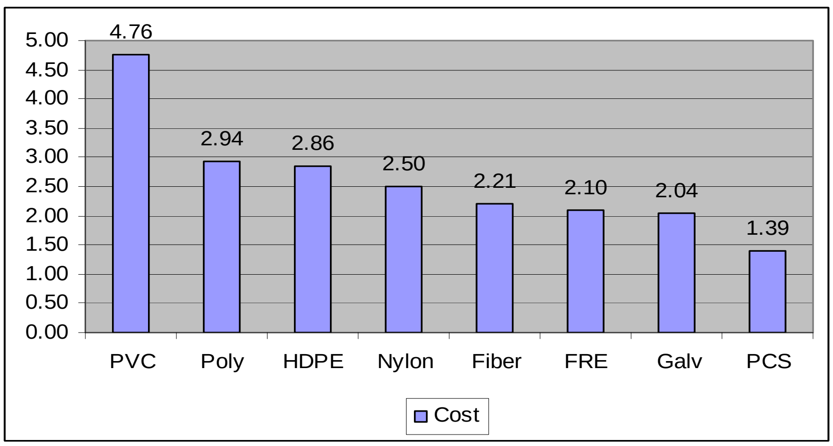

Figure 4.3.4: Cost of Conduit Materials

4.3.5 Overall Preference for Each Conduit Material

As described earlier, the stated preference for each material did not give a complete picture of the respondents' perceived value of each material. Figure 4.3.5.1 shows the average score for each material in the three areas of interest: Stated Preference, Ease of Installation and Cost, combined into one chart.

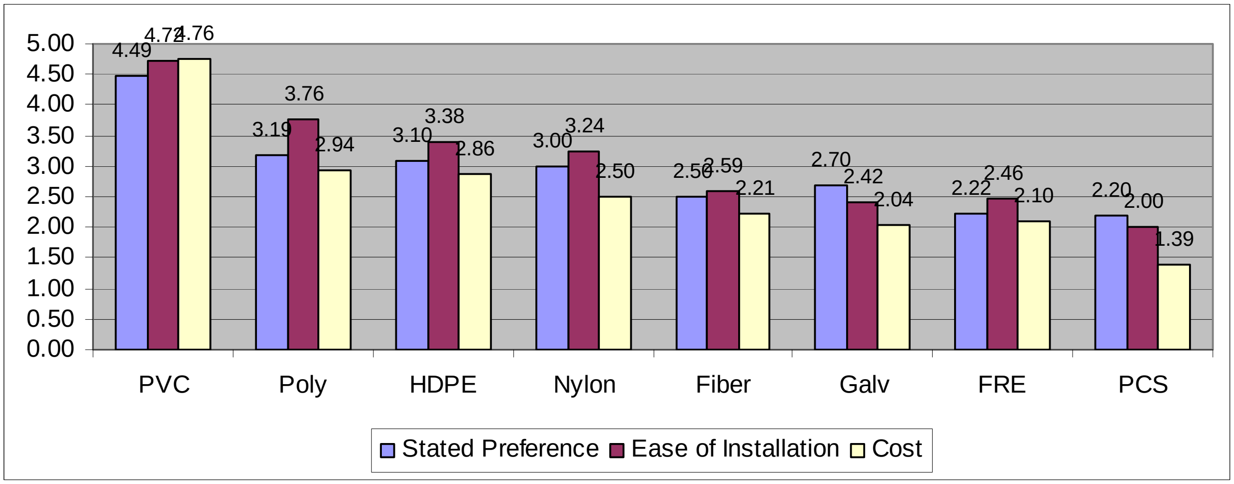

Figure 4.3.5.1: Stated Preference, Ease of Installation and Cost of Conduit Materials

By taking the average of the above three scores for each material, a simplified view of the respondents' perceived value of each material is gained, the resulting score is referred to as the "Overall Preference." Figure 4.3.5.2 shows a chart of the Overall Preference of each material by the survey respondents.

PVC received the highest overall rating with a score of 4.66, Polypropylene was second with 3.30, High Density Polyethylene was third with 3.11, Nylon was fourth with 2.92, Fiberglass was fifth with 2.43, Galvanized Steel was sixth with 2.39, Fiberglass Reinforced Epoxy was seventh with 2.26 and Polyurethane Coated Steel was eighth with 1.86. (See figure 4.3.5.2)

Compared to the charts for Ease of Installation and Cost, only Galvanized Steel and Fiberglass Reinforced Epoxy traded rankings. It is also interesting to note that the non-metallic materials were nearly all rated higher than the steel based materials. The conclusion can be made that respondents have a strong preference for PVC conduit, while all other alternative materials are grouped closely together. The total range of non-PVC alternatives was 1.44 or a range of thirty-six percent. This shows a discernable preference among survey respondents.

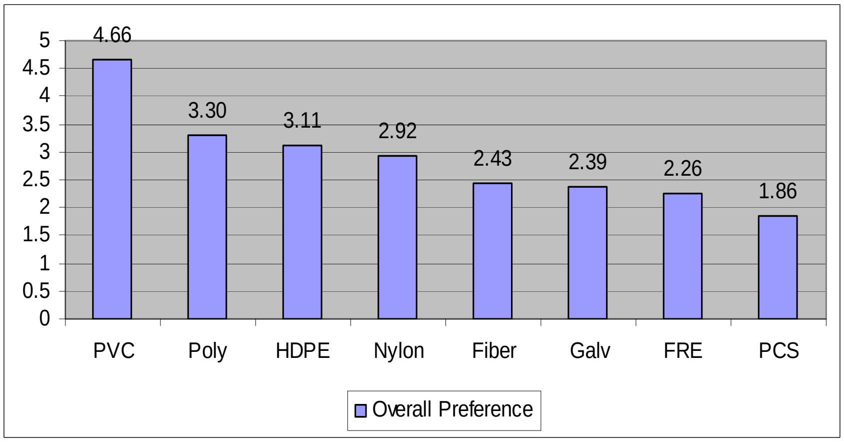

Figure 4.3.5.2: Overall Preference of Conduit Material

4.3.6 Overall Preference verses Respondents Who Have Used Each Material

By comparing the frequency of respondents who reported having used each material with the Overall Preference scores some important observations may be made. As shown in figure 4.3.1, PVC was the most commonly used material followed by Galvanized Steel. PVC was the most highly rated material while Galvanized Steel was one of the lowest rated materials. Figure 4.3.6.1 and 4.3.6.2, found below, shows a large gap between the number of respondents who have used a material and some of their preferences. Often there is a learning curve with materials and the longer a new material is used, or the more often it is used, the more efficiency increases. However, this figure shows that with the proposed alternatives there is almost a reverse trend. Polypropylene and High Density Polyethylene were the least used alternative materials but received the highest ratings of the non-PVC alternatives. Galvanized Steel and Polyurethane Coated Steel were the most widely used materials but received two of the lowest ratings. These ratings suggest that those who have used Polypropylene and High Density Polyethylene perceived a high value, suggesting that these materials should be used more often. A large negative gap, or a high number of users and a low rating, suggest that the materials usage should be reduced. PVC, Nylon and Fiberglass had ratings that appeared consistent with their usage. Figure 4.3.6.1 and figure 4.3.6.2; found below, both present the respondents' overall preference verses those respondents who have used each material.

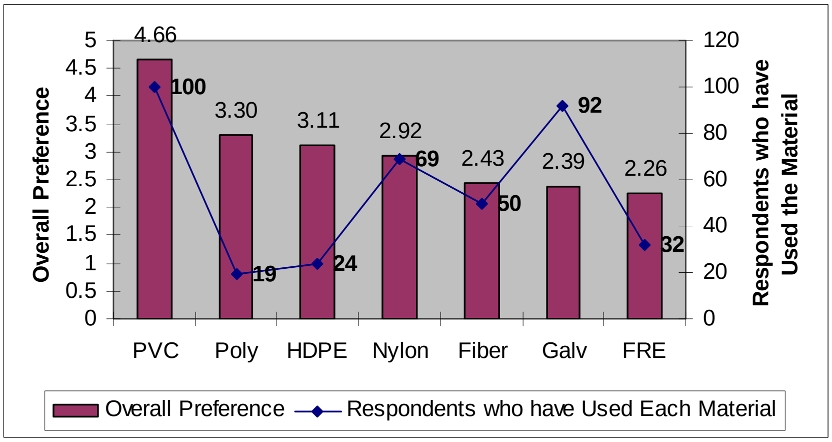

Figure 4.3.6.1 Overall Preference vs. Respondents Use of Each Conduit Material

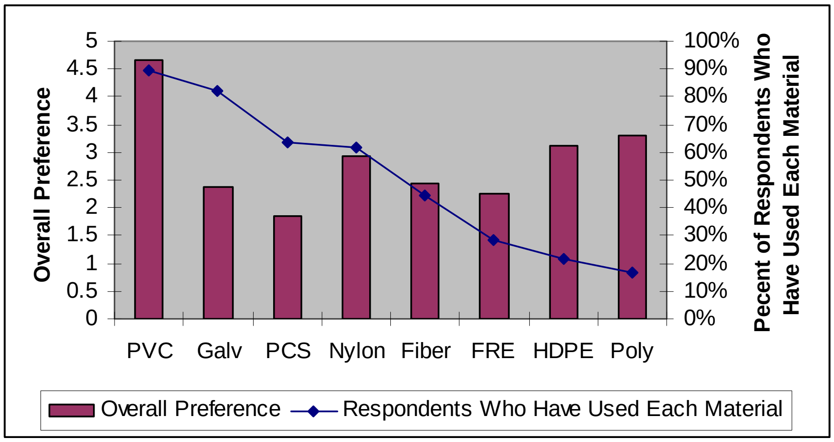

Figure 4.3.6.2: Overall Preference vs. Respondents Use of Each Conduit Material

4.3.7 Respondents' Awareness of Alternative Conduit Materials

Figure 4.3.7 shows respondents answers when asked to name their top two alternatives if PVC were eliminated. The responses were varied and do not correlate strongly with either the Stated Preference or Overall Preference ratings shown above, figures 4.3.2 and 4.3.5.2 respectively. One possible reason why the responses did not correlate with the results given in the analysis above is that respondents did not have strong feelings towards the alternatives in this study. The most common responses were other materials not listed in the research. Many of the responses were not viable underground materials with the most common response being "direct burial." Because of the open-ended response format of the question the responses are a good picture of the level of awareness about the alternatives proposed in the study. This indicates that in general, respondents did not have strong opinions or awareness about these materials. Of the materials in the study, Fiberglass was listed as the top alternative if PVC were eliminated. High Density Polyethylene was listed second, Galvanized Steel was listed third, Nylon was listed fourth, Polyurethane Coated Steel was listed fifth, Fiberglass Reinforced Epoxy was listed sixth and Polypropylene was listed seventh. (See figure 4.3.7)

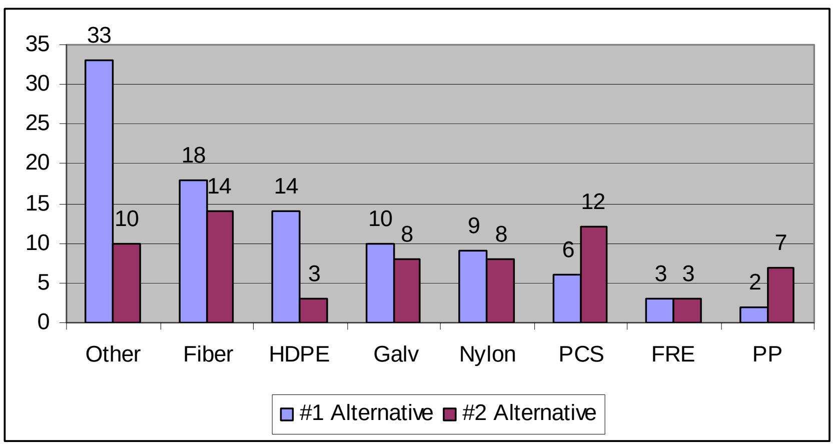

Figure 4.3.7: Open Ended Responses of Respondent's Top Two Alternative Conduit Materials

4.4 Respondents' Concerns about the Use of PVC Conduit

Respondents were asked to share their concerns or problems with the use of PVC conduit. Of the sixty-five written responses to this question sixty-six percent responded "none" or no concerns about using PVC. Twenty percent complained about the strength of the material; that it was brittle when cold or that it would sometimes burn when a leader pull cord was used to draw the electrical cables during installation. Eleven percent complained of the fumes from the glue used to seal PVC joints. Only one respondent mentioned toxic fumes when PVC was burned and one respondent said "It messes up the environment." Evidently, if environmentalists wish to persuade electricians that PVC is a toxic substance they need to make a greater effort to explain their case to the users of PVC conduit. (See figure 4.4)

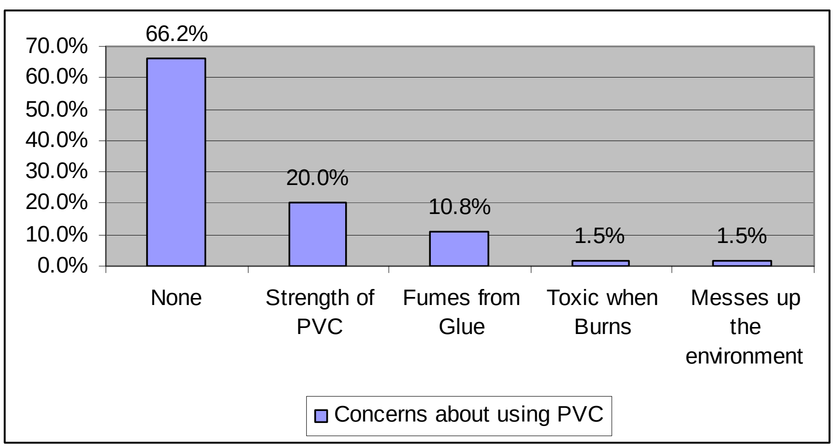

Figure 4.4: Respondent's Concerns about Using PVC Conduit

4.5 Respondents' Opinions about the Possible Elimination of PVC Conduit

Respondents were asked to share their opinions about the possible elimination of PVC conduit. Of the seventy-five written responses to this question only one respondent replied that elimination of PVC "Would be great for a greener planet," another said that "I don't like it but

I’ll live.” Thirty-one of the responses expressed concerns about raising the cost of project materials and labor. Eleven of the responses simply stated “Don’t do it.” A hand full of the responses stated “Stupid” or “Environmentalists are stupid” one even said, “Tell the tree huggers to stop worrying.” Overall, many of the respondents appeared to take the question personally and their emotion filled responses seemed to indicate resentment over being told what materials they were allowed to use. Four of the respondents expressed a willingness to use any material that was better than PVC.

4.6 Did Respondents Feel that a Green Certification Justifies the Elimination of PVC Conduit?

Respondents were asked a yes or no question if a green certification justified the elimination of PVC. Seventy-six percent of respondents felt that a green certification did not justify the elimination of PVC conduit, sixteen percent left no response to the question and only eight percent of the respondents answered that it did. (See figure 4.6) The majority of the respondents did not feel that a green certification would justify the elimination of PVC conduit. Responses documented in section 4.5 give a good indication as to possible reasons why such a strong majority felt that elimination of PVC was not justified.

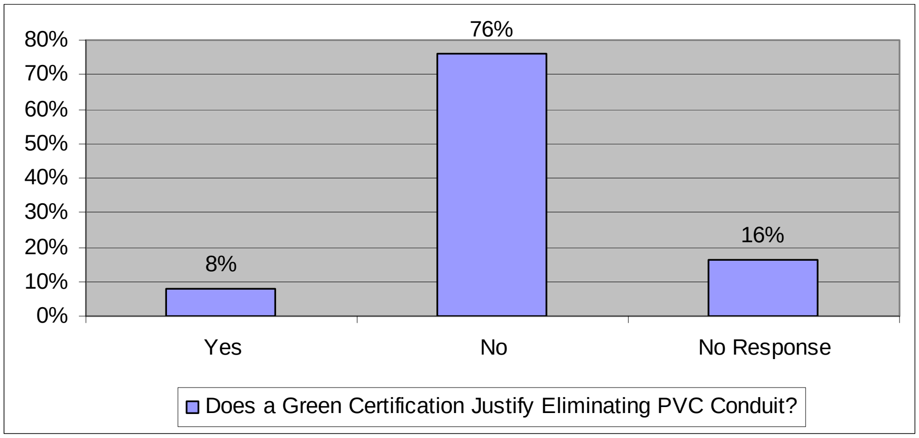

Figure 4.6: Did Respondents Feel that a Green Certification Justifies the Elimination of PVC Conduit?

4.7 Specific Conclusions

The purpose of this study was to evaluate the preferences of electricians in the state of Utah for PVC and alternative conduit materials for underground electrical applications. From a thorough review of literature and from answers provided by respondents, new information about these preferences emerged. New information and several conclusions can be drawn from this study.

- PVC is the most preferred underground electrical conduit of the materials considered in this study. It is regarded as the least expensive, easiest to install and favorite material of electricians working for a major electrical contractor in the state of Utah.
- Of the alternatives considered in this study Polypropylene is the most preferred, although the fewest number of electricians had experience with it. High Density Polyethylene was the second most preferred alternative, although the second fewest numbers of electricians had experience with it. Nylon conduit was also attractive to respondents, based upon the ratings and the number of electricians who had experience using the material.

- Most of the alternative materials were rated higher for perceived cost and ease of installation than Galvanized Steel conduit, which was the second most commonly used material.
- Galvanized Steel and Polyurethane Coated Steel were the least preferred alternatives but were the two most commonly used alternative materials in this study.
- Conflicting responses between the ratings and open ended responses suggest that respondents did not have strong opinions about the alternatives considered in this study. More could be done to expose electricians to these alternatives.
- Respondents to this study strongly felt that there is not enough value in green certification to justify the elimination of PVC.
- Respondents did not express concerns about the environmental impact of PVC or other concerns cited by those seeking to eliminate it.
- Respondents, who are some of the primary users of PVC, were not generally aware of the effort to eliminate PVC. Respondents expressed concerns about the impact such an effort would have on construction, costs and their personal employment.
- Many respondents appeared willing to adopt new materials if there was an increase in value.
- Respondents displayed an awareness of the impact that eliminating PVC could have on their company's well being.
- Responses indicated that the electricians' perceptions concerning the ease of installation and cost of a material usually correlated.
- For respondents, a more expensive material did not demonstrate an increase in value.

- Respondents displayed an attitude of doing the right thing for their company because that would benefit them personally. This sense of partnership with the company can allow for trial and error with new materials to determine if the alternatives identified in this study would in fact decrease costs or increase productivity, while improving the environmental impact of a project.

4.8 Summary

The results of this study indicate that PVC is not only the most common underground conduit material, it is also perceived to have the highest value. Polypropylene conduit was rated next highest, but the fewest number of respondents had used it. In general, respondents' attitudes did not appear overwhelmingly strong towards any of the environmentally friendly alternatives that were suggested by the Healthy Building Network. This indicates that the respondents were not exceedingly aware of these alternatives and that their opinions may not be based so much in experiences with each material but formed from other sources. In any case, there is room for education about these alternative materials. This is important, because like any new technology, alternative conduit materials need to show that they provide superior value to the existing technology if they are to gain wide spread use and acceptance.

CONCLUSIONS, RECOMMENDATIONS, FURTHER STUDY AND SUMMARY

5.1 Overview

The construction industry is dependent upon its ability to serve building needs. It must continually be prepared to adapt to changing conditions. An ever-evolving environment of social values, new technologies, materials, processes and market forces shape the future for successful construction firms. New technologies with improved electronic sophistication, automation, and information require increased wire and wireless connections in ever more complex structures. Modern technology has produced a huge demand for data facilities, which require vast amounts of wire, cables and conduit. For example, in fall of 2009, the federal government announced the new construction of a one and half billion square foot data center in Utah that is estimated to require as much electricity as all of the homes in Salt Lake City.[71] For comparison, a data center constructed in 2009 a few miles away in South Jordan was approximately one quarter of the size and required fifty-seven miles of underground PVC conduit. Increased social concern for the preservation of our environment and planet with attendant pressures to reduce pollution and the presence of hazardous materials, including chlorine based materials, conflict with many of the demands of modern society.

[71] M. LaPlante, "Camp Williams' NSA Data Center Will Mean Big Boost for Construction," *The Salt Lake Tribune*, 7 August 2009, available from http://www.sltrib.com/portlet/article/html/fragments/print_article.jsp?articleId=12772821&siteId=297; Internet; accessed 24 October 2009.

Polyvinyl Chloride (PVC) is the foremost material used in underground electrical conduit. Chlorine is its chief component, making PVC a prime target for elimination. Elimination pressures from various environmental groups have already led to increased restrictions, which has resulted in PVC being banned in some countries. In the United States, regulation and voluntary industry standards groups have been relatively moderate in the restriction of PVC, but pressures for additional limitations and even the elimination of PVC continue to increase. The primary installers of PVC underground electrical conduit are electricians employed by major electrical contractors involved in building structures to serve modern technologically oriented organizations.

A survey of electricians working for the four major electrical contractors in Utah revealed that the electricians are most familiar and comfortable with using PVC for underground conduit, they also feel that PVC is the most cost effective material. To a lesser extent, they are familiar with the use, benefits and costs of alternative conduit materials. They are also generally reluctant to change preferred materials without significant reasons or an increase in value.

The capability of experienced electricians and other construction professionals to change and adapt to new technologies and materials is obvious. However, they are unlikely to change proven methods and materials without significant pressure from market factors, including; demand, restrictions, cost savings and other incentives.

5.2 Recommendations for Major Electrical Contractors

The study provides a valuable starting point to increase experimentation with conduit materials that appear to be viable alternatives to PVC and may be more environmentally friendly. Major electrical contractors should be aware of changing market forces and the possibility of regulations which may produce a need to shift away from PVC. Electricians should be prepared to effectively use a variety of alternative conduit types, as organizations prepare to adjust and respond to new demands.

5.3 Recommendations for Those Seeking to Eliminate PVC

The environmental groups pushing for the elimination of PVC have relied heavily on government regulations, rather than the development of competitive alternatives or education about the benefits of existing alternative materials. An appeal to the users of PVC electrical conduit should focus on the value of new materials in terms of cost, ease of use and other benefits, rather than just a material's environmentally friendliness. Environmental friendliness alone did not appear to influence respondents enough to produce a change in voluntary behavior.

Attempts to coerce change through government regulations rather than an increase in value, builds resentment rather than good will. A few of the survey respondents indicated that they were willing to adopt a new technology if it provided superior value, but many others expressed resentment over being forced to use another material if it would affect them personally by increasing costs, decreasing the ease of installation or affecting their personal employment. Numerous responses indicated the perception that "costs of labor and materials would skyrocket" if PVC were eliminated. While these perceptions may not be accurate, they show that more should be done to persuade before governmental coercion is used.

It should be noted that the Healthy Building Network, while pushing for the elimination of PVC, has taken proactive steps to promote alternatives. Based upon the results of this study, many of these alternatives appear to be viable and provide a reasonable equivalent to PVC. The results of this study also indicate that many of the respondents were not very familiar with these alternatives and that their perceptions are not set in stone.

Some of the studies documented in the review of literature indicated that alternative materials have not been as critically examined as PVC. If so, why recommend one material over another if they cannot be measured impartially? Society, in general, has expressed increased interest in environmental issues in recent years. This interest should be validated through the use of impartial measurements and objective standards that lead to real improvements instead of emotional battles resulting in diminished use of efficient materials. Real value, increased efficiencies, market and social benefits should be the basis for changes in products and processes, including the selection of appropriate construction materials.

5.4 Recommendations for Further Study

- This study was limited to electricians' working for major electrical contractors in the state of Utah. Over six and a half percent of the target population responded to this study and offered their opinions and preferences on various alternatives to PVC conduit. Are their preferences consistent with respondents from other areas of the country? Further studies should determine if comparable attitudes and opinions are found in other regions and market situations.
- Manufactures advocating the use of PVC state that alternative materials listed as more environmentally friendly have not been critically analyzed to nearly the extent as PVC. This was one of the main considerations cited by the U.S. Green Building Council for not promoting the elimination of PVC. Are the other alternative materials considered in this study truly more environmentally friendly

than PVC? Further studies should establish an objective system to analyze construction materials to ensure impartial conclusions about environmental friendliness.

- This study was limited to electricians' preferences for alternative materials based upon their perceptions of product preference, ease of installation, and cost. Are their perceptions of ease of installation and cost accurate? Further studies should analyze ease of use, productivity and costs of the alternative materials identified in this study.

5.5 Summary

This study was an important first step in identifying preferences of electricians working for major electrical contractors in the state of Utah of alternative materials to PVC conduit in underground applications. It provides insight into the preferences of electricians, based upon use of a material, stated preference and ease of installation and cost. Among its findings it is revealed that PVC is the most commonly used and most preferred conduit material for underground applications. Conduit materials which have been recommended as environmentally friendly vary greatly in preference and in number of respondents who have used each material.

This study also showed that electricians did not see value in eliminating PVC to obtain a green certification but were likely to be open to alternatives if they provided an increase in value. Electricians' perceptions of alternative materials could change with further study and exposure, possibly leading to more widespread adoption.

The construction industry, including electrical contractors, must be aware and prepared for adjustments of practices and materials should greater restrictions on the use of PVC conduit become more evident.

Environmental groups seeking to replace PVC should focus more on the benefits and costs of PVC alternatives in order to achieve their goals.

Governments should not be reckless in adopting new standards for the increased regulation of PVC, as PVC is the most widely preferred and used underground electrical conduit. Further study is needed to impartially analyze the costs, benefits and environmentally friendliness of construction materials.

Building owners should be involved in examining the costs and benefits of alternative construction materials; as well as, constraints imposed by law or environmental standard.

The general public should be prepared to bear additional costs if they elect to accept less efficient building alternatives for the sake of environmental benefits.

Disagreements over the use of PVC electrical conduit illustrate conflicts and provide an opportunity for finding common ground by evaluating alternatives to satisfy society's needs and protect the environment.

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APPENDIX A. QUESTIONNAIRE

Underground Conduit Survey (For Electricians)

Certain environmental groups are pushing for the elimination of PVC and PVC conduit. Electricians use a lot of PVC conduit. Your willingness to answer this brief questionnaire may affect the materials you use in the future. ***This Survey is part of my graduation requirements at BYU. Thanks for your help! - Rob Andrus***

1. How many years of experience do you have as an electrician? ____________

2. Please provide your opinions on various types of underground conduit by completing the table below.

		1= Favorite 3= Average Preference 5= Least Favorite	1= Easy to Install 3= Average Install 5= Hard to Install	1= Cheap 3= Average Cost 5= Expensive
I've used it. ☑	**Underground Conduit Material**	**Preference (Rate 1-5)**	**Ease of install (Rate 1-5)**	**Cost (Rate 1-5)**
	PVC (Polyvinyl Chloride)			
	HDPE (High Density Polyethylene)			
	PP (Polypropylene)			
	Galvanized Steel			
	Fiberglass			
	Fiberglass Reinforced Epoxy			
	Nylon (Liquid Tight)			
	Polyurethane Coated Steel			
	Please list any other underground conduit material that you prefer.			
	1			
	2			

3. If PVC conduit were eliminated for underground use, what would be your top 2 alternatives? (in order)
   1. ______________________ 2. ______________________
4. In your opinion does a "Green certification" justify eliminating PVC conduit? Yes ____ No____
5. Please list any problems or concerns you have about using PVC. ______________________
6. Please share your opinion about the possible elimination of PVC conduit.
7. Name of your company. ______________________
8. What position do you currently hold? ______________________
9. Do you make purchasing decisions for your company? Yes____ No____

PLEASE RETURN SURVEY TO YOUR SUPERVISOR OR ROB ANDRUS (801-448-2599)

This questionnaire was reviewed and approved by Brigham Young University's Institutional Review Board for Human Subjects to ensure that the survey would not harm participants. If you have questions regarding your rights as a participant in research projects, you may contact Christopher Dromey, Ph.D, Chair of the Institutional Review Board for Human Subjects, 133 TLRB, Brigham Young University, Provo, UT 84602; phone, 801-422-6461. Researcher Rob Andrus, robandrus@yahoo.com. Your answers will remain confidential.

APPENDIX B. RAW DATA

Years of Exp.		PVC		4.66		HDPE		3.11		PP		3.30		Galv		2.39		Fiber		2.43		FRE		2.26		Nylon		2.92		PCS		1.86	
	14.6	83%	4.49	4.72	4.76	16%	3.10	3.38	2.86	13%	3.19	3.76	2.94	76%	2.70	2.42	2.04	40%	2.60	2.59	2.21	25%	2.22	2.46	2.10	66%	3.03	3.24	2.50	58%	2.20	2.00	1.39
	14.6	93	1.5	1.3	1.2	18	2.9	2.6	3.1	14	2.8	3.2	3.1	88	3.3	3.6	4.0	45	3.5	3.4	3.8	28	3.8	3.5	3.9	63	3.0	2.8	3.5	65	3.8	4.0	4.6
Survey #		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	24	1	1	1	1									1	2	3	3													1	3	5	5
2	24	1	1	1	1									1	2	3	2																
3	37	1	1	1	3									1	3	3	3																
4	15	1	3	1	1									1	1	4	4	1	4	3	4									1	3	1	3
5	1	1	1	1	1																												
6	36	1	1	1	1									1	2	2	2													1	3	3	3
7	45		1	1	1		1	1	3		1	1	3		3	3	4		3	3	3						4	4	4		3	3	5
8	21	1	1	3	1									1	5	3	5	1	5	3		1	5	3		1	3	3		1	5	5	5
9	20	1												1												1				1			
10	10		3	1	1		5	5	5						3	2	2																
11	13	1	3	1	1	1	3	3	4					1	2	1	5	1	4	3	3	1	4	4	3	1	3	4	3	1	2	1	5
12	13	1	1	1	1	1	3	3	3	1	1	1	3	1	5	5	5	1	5	5	5	1	5	5	5	1	5	5	5	1	3	1	3
13	1	1	1	1	1		3	2	2		3	2	3	1	5	5	4	1	3	3	5	1	3	3	5	1	2	2	3	1	5	5	3
14	28	1	1	1	1		5	5	5		5	5	5		1	1	1		5	5	5		5	5	5		5	5	5		1	5	5
15	3	1	1	1	1									1	3	3	3									1	3	3	3				
16	15	1	1	1	1									1	3	3	3									1	1	1	5	1	5	5	5
17	25	1	1	1	1									1	3	5	4					1	4	3		1	3	2		1	3	4	5
18	8		1	1	1		5	5	5		5	5	5		1	1	1		5	5	5		5	5	5		5	5	5		1	1	5
19	3		1	1	1		3	3	3		3	3	3		5	5	5		3	3	3		3	3	3		3	3	3		5	5	5
20	2	1	3	3	1									1	3	5	5	1	4	4	4					1	3	3	3				
21	22		1												3												3				3		
22	12	1	3	3	1									1	3	3	3	1	2	3	3	1	3	3						1	1	1	
23	8	1	5	5										1	3	3														1	1	1	
24	30		1	1	1		1	1	1		1	1	1		5	5	5		5	5	3		3	5	3		1	1	3		5	5	5
25	4	1	3	3										1	2	3		1	5	5		1	3	3		1	3	3					
26	35	1	1											1	5			1	3							1	1						
27	10	1	3	3	3	1	3	3	3					1	5	5	5	1	3	3	3					1	3	3	3	1	5	5	5
28	15	1	1	1	3					1	3	1	3	1	1	1	5									1	3	1	3	1	5	3	5
29	4	1	1	1	1									1	5	5	5	1	4	4	4												
30	9	1	3	1	3									1	1	5	3									1	5	3	3				
31	4	1	1	1	1									1	1	4	4	1	2	3	3	1	2	3	3	1	2	1	3	1	5	5	5
32	6.5	1								1				1				1												1			
33	10	1	1	1	1									1	2	3	3	1	3	5	5												
34	21	1	1	1	1	1	1	1	5	1	2	2	5	1	3	3	5	1	4	4	4	1	5	3	3	1	5	5	2	1	5	5	1
35	10	1	3	1	1									1	1	1	3					1	3	3	5	1	3	1	3	1	5	3	5
36	3	1	1	1	1					1		1	1	1		5	5	1		3	5	1		3	5	1		1		1		5	5
37	15	1	1	1	1	1	3	3	3	1	1	1	1	1	5	5	5	1	3	3	3					1	1	1	1	1	5	5	5
38	19	1	1	1	1					1	1	1	1	1	1	3										1	1	1	1	1	1	3	5
39	8	1	1	1	1									1	2	2	2					1	5	5	5	1	4	4	4	1	5	5	5
40	4	1	3	1	1									1	1	3	3									1	3	3	3				
41	10	1	1	1	1					1	3	2	4	1	5	3	3	1	3	2	5					1	3	1	5				
42	13	1	1	1	1	1	2	1	3					1	4	4	5	1	3	2	3	1	3	2	3					1	3	4	5
43	13	1	2	1	1	1	1	1	2					1	5	5	5	1	4	3	3	1	4	3	3	1	3	2	4	1	5	5	5
44	12	1	1	1	1	1	1	1	2					1	5	5	5									1	3	4	4	1	5	5	5
45	19	1	3	1	1	1	3	1	1					1	3	5	5	1	3	3	3	1	3	3	3	1	3	3	3	1	3	3	3
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47	22	1	1	1	1					1	3	1		1	3	5	5	1	1	1						1	3	3		1	1	5	5
48	33	1	1	1	1									1	5	5	5	1	3	3	3	1	3	1	3					1	5	5	5
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50	31	1	1	1	1									1	4	4	4									1	3	3	3	1	5	5	5
51	11	1	1	1	1									1	3	4	4	1	3	2	3	1	3	2	3	1				1	5	5	5
52	30	1	1	1	1	1	2	2	2	1				1	5	5	5									1	1	1	2	1	5	5	5
53	4	1	1	1	1									1	3	3	5									1	5	3	5	1	5	5	5
54	20	1	1	1	1									1	4	4	3	1	2	2	2									1	3	3	4
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56	4		1	1	1		5	5	5		5	5	5		5	5	5		5	5	5		5	5	5		5	5	5		5	5	5
57	4	1	1	1	1									1	5	3	3																

58	6													1								1								1			
59	11	1	1	1	1																					1				1	1	3	5
60	23		1	1	1		1	1	1		1	1	1		5	5	3		3	5	5		3	5	5		3	5	5		5	5	5
61	11	1	1	1	1																									1	1	3	5
62	24	1	3	3	1		3	3	3		3	3	3		5	5	5		5	3	3		5	3	3		5	3	3		5	1	
63	10	1	1	1	5									1	5	5	5									1	3	1	5				
64	30	1	1	3	3									1	1	3	5									1	1	1	1				
65	8	1	3	1	1									1	3	3	3									1	3	1	3				
66	10	1	1	1	1					1	3	3	3													1	3	1	3				
67	4.5	1	1	1	1									1	5	5	5																
68	13	1	1	1	1									1	5	3	3	1	3	3	3									1	5	3	3
69	12	1	5											1	5			1	5			1	5			1	5			1	5		
70	6		1	1	1		1	1	1		4	4	3		4	4	4		2	2	4		2	2	4		4	4	4		5	5	5
71	6	1	1	1	5									1	5	5	5									1	1	3	5	1	5	5	5
72	4		3	1			4	3			2	3			3	5			3	2							2						
73	14	1	5	1	1	1	5	3	3	1	5	3	1	1	5	5	1	1	5	5	3	1	5	5	3	1	5	3	3	1	5	3	3
74		1	1	1	1			5	5		5	5	5	1	5	5	5		5	5	5		5	5	5	1	5	5	5		5	5	5
75	8		3	3	3		5	5	5						4	3	5		3	3	3						1	1	3		5	5	5
76	1		3	1	1		5	2	3		1	3	2		3	3	5		1	1	5		1	1	5		1	1	1			1	1
77	4	1	1	1	1	1	1	1	1					1	3	3		1	5	3													
78	12	1	5	1	1									1	2	4	4									1	2	2	3	1	1	5	5
79	25	1	5	5	5	1	4	4						1	3	3						1	3	3									
80	16	1	1	1	3									1	3	3	3									1	3	1	3	1	3	3	3
81	4	1	1	1	1									1	5	5	5	1	3	3	5					1	3	1	3	1	5	5	5
82	15	1	3	1	1									1	3	5	5					1	3	1		1	5	1	5	1	3	5	5
83	5	1	1	1	1									1	5	3	3																
84	20	1												1												1				1			
85	17	1																								1				1			
86	8	1	1	1	1									1	5	5	5	1	3	3	5									1	5	5	5
87	9	1	1		1									1	4		4	1	2		3									1	5		4
88	39	1												1				1												1			
89	10	1	1	1	1																					1	3	3		1	5	5	
90	12	1	1	1	1									1	3	3	5	1	4	5	5	1	4	5	5	1	3	3	3	1	5	3	5
91	18	1	1	1	1									1	5	5	5									1	3		3	1	3	5	5
92	6	1	1	1										1	3	4		1	4	3						1	2	2					
93	11	1	1	1	1									1	5	5	5	1	3	3	3					1	3	3	5	1	5	5	5
94	10	1	1	1	1										3	3	5										1	1	1				
95	41	1	1	1	1		5	3	3		5	3	3	1	5	5	5	1	3	2	5		3	3	3	1	3	3	3	1	5	5	5
96	39	1	1	1	1									1	5	5	5				5	1	2	2	3					1	5	5	5
97			1	1	1										4	4	4														5	5	5
98	50	1	1	1	3	1	3	3	5					1	5	5	5	1	1	1	1									1	5	5	5
99	11	1	1	1	1		5	5	5		5	5	5		5	5	5	1	5	5	5		5	5	5	1	5	5	5		5	5	5
100	2	1	1	2										1	4	3						1	3	3		1	2	3					
101	7		1	1	1		3	1	3		3	1	3		5	5	5		3	3	5		3	3	5		5	5	5		5	5	5
102	4	1	1	2	1									1	3	3	3					1	5	5	5	1	2	1	4	1	3	1	5
103	17	1	1	1	1									1	3	5	5									1	3	3	3	1	5	5	5
104	11	1	1	1	1									1	3	3	3									1	3	1	3	1	3	5	5
105	3	1	1	1	2	1	2	2	3									1	1	1	4	1				1	3	3	4				
106	2.5	1	1	1	1									1	2	3	5	1	5	1						1	1	1	4	1	5	5	5
107	15	1	1							1	3			1	3			1								1				1			
108	5	1	1	1	1									1												1	3	3	3				
109	25		1	1	1		3	3	3		3	3	5		5	5	5		5	3	5		3	3	5				5		5	5	5
110	33	1	1	1	1									1	3	3	5	1	2	1	3									1	6	6	6
111	15	1	1	2	1	1	1	1	2					1	3	3	3													1	4	4	4
112	9	1	3	1	1									1	5	5	5																

APPENDIX C. CONCERNS REGARDING THE USE OF PVC

LIST OF CONCERNS ABOUT USING PVC CONDUIT (RAW DATA)

Concerns
None
None
shape consistency
brittle, breaks
strength
None
strength
Easy to break in excavation
None
None
Smell of Glue
Toxic fumes flammable
Brittle in cold
None
None
None
None
Joints not holding
excavation
None
None
None
Fumes
None
Fumes
strength
PVC is great
None
None
strength
None
None
None
None
Cracking, shrinking
Glue
Rope burns PVC elbows
Glue
None
None

None
None
None
None
None
None
None
Mess up environment creating and using it, Glue is deadly
Bigger sizes hard to install
Install hard
Leaking
None
Glue
None
Breaks Easily
None
Breaks Easily
None
Not in favor unless there is a better alternative
None
None
None
None
None
None
None
None
None
None
PVC is great
None

APPENDIX D. OPINIONS ON THE POSSIBLE ELIMINATION OF PVC

OPPINIONS SHARED ABOUT THE POSSIBLE ELIMINATION OF PVC
Cost to go up. Conduit will corrode
Should not be eliminated
Would not do it.
Other than small branch it should never be used
don't eliminate
cost of alternatives is not practical
Skeptical of motivation for elimination
It would create more problems. PVC lasts longest
Make job more expensive, and slower
Raise Costs, More time
don't eliminate
Will install what is provided
Raise Costs, More time
don't eliminate
Raise Costs, More time
Raise Costs, More time
Don't do it.
Green is stupid
easy to use
Please don't
PVC is cheap and easy
Don't do it.
Don't do it.
If something better comes along then I'm all for it.
Don't do it.
costs, skill
Raise costs, mean fewer jobs
Too many environmental restrictions
Cost, Time
Cost
Cost
Cost
Don't do it.
It would double material & labor costs
Don't do it.
Not good
Raise Costs, More time
Raise Costs, More time
Don't do it.
PVC is good because it doesn't decompose
It will slow production
If there is something better then lets do it.

Its crazy
PVC is cheap and lasts
I don't like it but I'll live
Stupid
Doesn't matter to me
Please don't
PVC is most effective in everyway
That would be great for a green planet
My world would end
There is no good alternative, it works great. Costs for underground would skyrocket. Metal is expensive and labor intensive.
Elimination is extreme, maybe find a better alternative that's healthier for the environment
A little excessive
Drastically increase the cost of underground conduit.
Will increase costs of labor and materials
PVC is a good product
Will make underground harder to do.
Only to replace greenhouse gas
Bad Idea
easy to use
Major Cost Impact, Schedule, time on job
Raise Costs, More time
Raise Costs, More time
No problem as long as it is replaced with something better.
Install time will increase
Stupid, Increase costs
Cheap and Easy to use
Tell the tree huggers to quit worrying
Not a good idea
It will never happen
Install will be a pain
Raise Costs
Cost of Steel is prohibitive, HDPE is the future
Not good

APPENDIX E. CERTIFICATION FROM BRIGHAM YOUNG UNIVERSITY'S INSTIUTIONAL REVIEW BOARD

INSTITUTIONAL REVIEW BOARD FOR
HUMAN SUBJECTS

September 10, 2009

Robert Andrus
1805 Andrus Lane
Provo, UT 84604

Dear Robert,

Thank you for your recent correspondence concerning your protocol entitled "A Study of Electricians' Preferences of Alternatives to PVC in Underground Conduit." Brigham Young University's Institutional policy requires review of all research. I appreciate your willingness to comply with this policy.

According to the Code of Federal Regulations 45.46.102 (f), in order for research to be considered Human Subjects research, an investigator conducting research will obtain

- Data through intervention or interaction with the individual, or
- Identifiable private information

Whereas, **Intervention** includes both physical procedures by which data are gathered and manipulations of the subject or the subject's environment that are performed for research purposes. Interaction includes communication or interpersonal contact between investigator and subject. **Private information** includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public. Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator or associated with the information) in order for obtaining the information to constitute research involving human subjects.
http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.htm#46.102)

Your research will collect data from individuals about PVC conduit preferences and not their personal, private information.

Your protocol has received Administrative approval. You are approved to begin your research. You should assure research subjects that participation in your project is "voluntary" and information will be kept "confidential."

If you have any questions, please do not hesitate to contact me, (801) 422-1461, A-285 ASB. I wish you well with your research!

Sincerely,

Sandee M.P. Muñoz, Administrator
Institutional Review Board for Human Subjects

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