



PIPES NEED JACKETS TOO

Improving Performance of BC
Buildings through Mechanical
Insulation Practice and
Standards - A White Paper



PREPARED FOR
**International Association of Heat and
Frost Insulators and Allied Workers
(IAHFIAW) – Local 118**

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Mechanical insulation presents an enormous opportunity for energy and cost savings plus health and safety benefits in the construction, maintenance and liveability of British Columbia's buildings.

However, there are numerous issues in its proper implementation and application. This White Paper details the issues and offers wide-ranging recommendations for their resolution, and provides a comprehensive overview of the benefits of mechanical insulation.

The contents address an array of standards, regulations and strategies that will help our province combat greenhouse gas emissions while cutting costs and improving the safety and durability of the mechanical systems in our buildings.

**Improving Performance
of BC Buildings through
Mechanical Insulation
Practice and Standards**

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Executive Summary

1. Overview

A timely opportunity exists in British Columbia to reverse a trend of deteriorating building practice, save millions of dollars per year in energy costs and contribute to provincial climate change goals – the opportunity is the typically unseen insulation on pipes and ducts of heating and cooling systems, known as *mechanical insulation* (MI). Based on a survey of peer-reviewed research and trade journals, interviews with a wide range of professionals who work with mechanical insulation and energy modeling of three different building types, we have identified actions that can be taken by the provincial government, utility companies, local government, developers, engineers and building owners/operators that can save millions of dollars and eliminate thousands of tonnes of greenhouse gas emissions each year.

Increasingly in recent years, concerns have come to light regarding poor installation practices in mechanical insulation for building construction in BC. Local and global goals to use energy more wisely and reduce greenhouse gas emissions heighten the urgency and opportunity for taking action in the short term. This paper was independently authored by HB Lanarc Consultants and commissioned by the International Association of Heat and Frost Insulators and Allied Workers (IAHFIAW—also known as the Heat and Frost Insulation Union) in order to more formally recognise the opportunity to meet energy and greenhouse gas reduction goals through reversing the trend of poor mechanical insulation installation practices. IAHFIAW members install the mechanical insulation for a large percentage of the multi-unit residential and commercial buildings in British Columbia. Its members, through partner organisations such as the BC Insulation Contractors Association (BCICA) have written training curriculum for mechanical insulation that is used by similar organisations across North America.

Mechanical insulation, as one of the many components of a building energy system, plays an important role in:

- 1.** Improving energy efficiency, thereby mitigating greenhouse gas emissions and moving toward sustainable energy use;
- 2.** The economic performance of buildings, including minimizing spending on energy and ensuring durable buildings; and
- 3.** Health and safety—through fire stopping and protecting workers/building occupants from unhealthy indoor air quality (moisture-caused mould) and burn (exposed pipes).

British Columbia has in place some of the most aggressive greenhouse gas reduction targets in the world. Energy efficiency requirements have been increased in the BC Building Code, and much more aggressive changes are anticipated in the near future. Provincial energy and climate change legislation, including the BC Climate Action Plan, Clean Energy Act of 2010 and the BC Clean Energy Plan, have set goals and established priorities for reducing energy and emissions through efficiency, and identifies the need to identify economic development strategies, including “green collar jobs” that advance these goals. Mechanical insulators clearly fall into this category. Many local governments in BC are also strongly encouraging green, energy efficient buildings. Meeting these increasing building performance regulations requires new design practices and technology, and consistent application of best practices in construction. Unfortunately, achievement of energy performance targets is being hampered by poor

installation practices related to mechanical insulation. Millions of dollars can be saved each year by building owners, operators and tenants in British Columbia by improving mechanical insulation practices – mainly due to less wasted energy and increased service life of equipment. Poor insulation practices can also put health and safety at risk due to potential injury.

2. Gaps in Codes and Standards

Mechanical insulation best practice consists of choosing the right materials for each application, installing the appropriate thickness of insulation, and using appropriate techniques for securing and fastening the insulation in place. However there is no single established code, standard or best practice guide in BC that addresses all three of these areas.

- Neither the Model National Building Code, nor the BC Building Code include thickness tables for mechanical insulation, though they do contain fire and worker protection requirements.
- While the BC Building Code and Vancouver Building Bylaw make reference to ASHRAE Standard 90.1¹, the ASHRAE standard does not contain a section specifically dedicated to mechanical insulation, nor does it address best practice. The ASHRAE 90.1 standard includes specification tables for mechanical insulation thicknesses, but these are not reproduced in either the BC code or Vancouver Building Bylaw.
- ASHRAE Standard 189.1-2010 specifies mechanical insulation thermal resistance (R-values) and could in time supersede ASHRAE 90.1 in terms of building code references, though it appears there are no current plans to do so.
- The BC Insulation Contractors Association (BCICA) has created a Quality Standards for Mechanical Insulation manual that comprehensively covers installation practice, but does not reflect current best practices for insulation thicknesses.

The need to consult a building code, a standard and a best practice manual in order to assemble the complete set of information needed to write an engineering specification and properly install mechanical insulation has created confusion among industry professionals with numerous different interpretations of what is required by “code” versus “best practice.”

3. Findings on the State of Practice

Industry literature suggests that there is significant non-compliance with building codes and best practices. A broader survey of various building industry members and stakeholders corroborated this and indicated that:

- Oversight of mechanical insulation design and installation by local government building departments is very limited, and varies significantly across BC; and
- There is frequent non-compliance with the Building Code. Estimates vary within local governments of the rate of non-compliance with aspects of the code, however municipal building officials interviewed cite frequent code violations of some form.

¹ The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) is an international technical society for all individuals and organizations interested in heating, ventilation, air-conditioning, and refrigeration. Standard 90.1 is an Energy Standard for Buildings excluding low-rise residential buildings.

Additionally, examples of mechanical insulation deficiencies in built projects have been documented by a co-author of this study, Besant and Associates Engineers, as part of many building audits and investigations.

The following table summarizes common deficiencies identified, and the types of impacts that these deficiencies can result in.

Table 1 – Common Mechanical Insulation Deficiencies and their Impacts

Deficiency	Effects or Impacts
No insulation (either not installed, or removed by maintenance contractors)	Excessive heat transfer
	Pipe or duct deterioration due to corrosion
	Risk of injury, e.g. from burns or sharp corners
	Condensation will increase heat rates and may damage building structures
	Energy efficient systems may not perform as specified
Improper installation	Same as above
Insulation removed by maintenance contractors	Same as above
No mechanical protection for insulation	Insulation removed by pests or damaged by the environment
	Vandalism damage to insulation
Improper selection of materials for insulation	Damage to insulation due to heat, corrosion or physical abrasion
	Excessive heat transfer and potential damage to the insulation
	Energy efficient systems may not perform as specified

The reasons for poor practice in the industry (identified during interviews) are numerous, and include:

- Outdated or incomplete engineering specifications, or lack of knowledge of best practices by engineers, especially for newer, high performance and low-temperature systems;
- Problems due to unqualified installers and inadequate training;
- Lowest cost tendering and “value engineering,” reducing costs below what is necessary for best practices, particularly when the developer is not the eventual owner or operator;
- A perception among some developers and engineers that mechanical insulation is not a critical building component. This may be due in part to lack of educational focus on this issue;
- Poor quality, lower cost insulation materials on the market;
- Challenges related to engineering field review, including assessing whether installations meet code and design specifications;
- A fragmented design and construction process where engineers and installers do not typically work closely together; and
- Tight construction timelines and focus on drywall completion, which can prevent inspection of some systems.

“The engineers that inspect the work do not know what constitutes best practice. If they do, they are rarely able to tell when an installation has occurred that does not meet the specifications.” – Local Building Code Inspector

“The installation and inspection system currently lacks checks and balances. The incentives to cut corners out-weigh the costs from the perspective of the installers and the mechanical engineers....

There is bragging among contractors as to who can get away with the most regarding cutting corners and doing work that is not performed to specifications.”

– Mechanical Insulation Contractor

Non compliance plus poor practice has resulted in a major lost opportunity to reduce energy use and GHGs and save money. Based on our economic analysis of a simple case study that looked at installed costs, maintenance and energy saved, we found that the costs of fitting mechanical insulation on hot water pipes, for instance, can be recovered quickly—usually in less than five years. In addition, our case studies indicate that energy savings associated with pipe insulation can account for a significant proportion of overall building energy consumption. This suggests that without proper mechanical insulation, buildings are consuming more energy, and producing more greenhouse gas emissions than necessary.

A high level analysis of energy savings and greenhouse gas reduction opportunities for British Columbia as a whole from improved mechanical insulation practice and standards showed that:

- Potential Annual Energy and Greenhouse Gas Reductions from performing Mechanical Insulation Retrofits on Existing Multi-unit Residential and Commercial Buildings = **200 – 500 GWh** and **35,000 – 90,000 tonnes CO₂e**; and
- Potential Energy and Greenhouse Gas Reductions in the Year 2020 from Improving Mechanical Insulation Practice and Standards on New Multi-unit Residential Buildings = **60 - 120 GWh** and **10,000 – 20,000 tonnes CO₂e**.

Cost implications of insulation issues and deficiencies can extend to mechanical system failures, which can have dramatic capital and maintenance cost impacts. Insulation, when properly applied, can prolong the service life of equipment, pipes, ducts and the building.

4. Recommended Strategies

Based on the results from interviews with industry experts and analysis of policies and codes within and external to BC, a set of recommendations were developed in order to improve mechanical insulation practice in BC.

From a strategic perspective, it is clear that a unified and compelling set of changes at the senior government level, supported by local government policies, is needed to achieve a consistent, improved level of performance across BC. The reasons for insulation deficiencies are complex and interrelated;

therefore a single solution, such as regulatory changes alone, will probably not result in the best possible outcomes. To address these issues, two mutually reinforcing strategic elements are recommended:

1. Provide a consistent regulatory framework across BC that embeds standards for mechanical insulation in building codes; and
2. Build capacity in local government and industry (i.e., development and construction) to maximize compliance with codes, standards and best practices, both existing and future.

The individual recommendations have been divided into the categories of Senior Government, Local Government, Utility Incentives and Education/Capacity Building:

1. Senior Government Action and Building Codes

i. Update the BC Building Code and Vancouver Building Bylaw to include specific, up-to-date requirements on mechanical insulation.

- Include a clear, mandatory requirement for mechanical insulation in Part 3 buildings, referencing minimum insulation requirements tables as per the appropriate version of ASHRAE 90.1. e.g., ASHRAE 90.1-2004 for the existing BC code; to be updated as the building code references newer versions of ASHRAE standards.
- Include references to mechanical insulation best practice standards, such as:
 - Include clear qualification requirements for mechanical insulation contractors and installers.
 - Further distinctions around the applicable minimum building scale/type may be warranted.

ii. Update the National Building Code and Model National Energy Code for Buildings with up to date requirements on mechanical insulation.

- The Thermal Insulation Association of Canada and other industry representatives and consultants have been providing recommendations to the NRC Canadian Codes Centre concerning updates to future versions of the National Energy Code for Buildings.

iii. Require that building officials (or third party independent inspectors) are tasked with mechanical system inspections.

- Given the potential impact of mechanical insulation deficiencies, the province should require mandatory local government site inspections, including mechanical systems and mechanical insulation, to augment the field reviews conducted by the registered professional.

2. Local Government Policies and Programs

Examples of local government policies and programs include the following.

i. Create or update Development Permit Checklists – Planning Departments

- A number of local governments already require developers to complete sustainability checklists as part of development permit processes. Generally these checklists are mandatory to complete, but the local government does not (and cannot) require a minimum criteria with regard to energy performance or completion of checklist items that overlap with the building code scope.

ii. Create or update Building Permit Checklists – Building Approvals Departments

- Require the incorporation of a mechanical insulation checklist as an element of a Building Permit application for Part 3 buildings – i.e. commercial, institutional and industrial buildings, optionally of a minimum size. This checklist item could also be part of a sustainability checklist (if one exists) for building permit applications. As explained above, compliance with checklist items would generally be voluntary, though completion of the checklist could be made mandatory through the building bylaw.

iii. Municipal building construction and retrofits – Facilities and/or Purchasing Departments

- Local governments can take steps to minimize energy and cost performance impacts of mechanical insulation deficiencies in their own buildings, as well as gaining experience and showing leadership on energy efficient building practice.
- Incorporate policy and/or procurement guidelines that require mechanical insulation best practices to be included in construction and retrofit RFPs and tenders.

iv. Building Bylaw requirements for qualified mechanical insulation contractors – Planning/Engineering Departments

- Though requiring minimum energy performance or specific best practices is generally not within local government authority, a local government could² require developers to ensure that mechanical insulation contractors are qualified under a recognized mechanical insulation certification program as a part of rezoning negotiation (as mentioned in the Senior Government Action section earlier). However, this requirement is ideally implemented at a provincial level.

v. Build staff capacity to address mechanical insulation issues – Planning, Engineering and Building Approvals Departments

- Local government education and training programs can support all the above actions. Refer to the Industry and Local Government Education and Capacity Building section later for more information.

3. Utility Incentive Program

- BC Hydro, Terasen Gas and Fortis BC should put in place rebate programs for both commercial and residential customers that include mechanical insulation. The costs to the utility companies to provide an attractive rebate on insulation would be less than many of the other products that are currently included in financial incentive programs because of the low cost of insulation compared to the mechanical systems that they are associated with (1/10th of the cost, as a general rule of thumb). Because of its role in setting Provincial energy policy and targets, the B.C. Ministry of Energy could collaborate with the Building and Safety Standards Branch of the Ministry of Public Safety and Solicitor General to ensure that mechanical insulation is included among the technologies/practices that are targeted by building energy efficiency programs.

4. Industry and Local Government Education and Capacity Building

- Work with industry and professional associations to advance education and training opportunities and market penetration, including promotion of existing initiatives like the BCICA QA program.

² A review of the legality of this authority is recommended.

- Work with local governments and associations (such as the Union of BC Municipalities) to develop and promote education and training opportunities for staff, particularly building inspectors. The scope of this education and training could parallel that for industry, but would likely have a focus on inspections.
- Write a technical bulletin on the mechanical insulation requirements in ASHRAE 90.1 and the BC Building Code and disseminate this to building inspectors, engineers and the Building Policy Advisory Committee within the Ministry of Public Safety and Solicitor General.
- Work with TIAC and BCICA to include a sustainability section in their standards/guidelines, informed by the findings in this report.
- Develop a third party inspection qualification program to support local governments in the absence of a clear mandate for local government building inspections, and work with educational institutions (e.g. BCIT) to deliver the education programs.

I. Introduction

This White Paper project was initiated in May 2010, when the International Association of Heat and Frost Insulators and Allied Workers (IAHFIAW—also known as the Heat and Frost Insulation Union) commissioned HB Lanarc to write the paper. HB Lanarc conducted an industry survey and modeling analysis, and drafted this White Paper, independently of the IAHFIAW. The Heat and Frost Insulation Union and its members have been working to improve practices through educating engineers, creating training curricula and installing insulation for more than 100 years. They also operate an apprenticeship program that is the primary training resource for new mechanical insulation installers. The Heat and Frost Insulators approached HB Lanarc so that an independent perspective could be brought to the issue and a set of solutions proposed that includes construction and land developers, building owners, local governments, the Province and utilities.

This White Paper’s intended audience includes:

1. Provincial and federal building code authorities
2. Utility companies
3. Local government elected officials and staff, including:
 - a. Building officials
 - b. Engineers
 - c. Planners
 - d. Sustainability personnel
4. Trade associations and professionals with an interest in improving the quality of construction in British Columbia
5. Land and building developers
6. Large commercial building owners and managers

It is hoped that these groups will consider the analysis in this White Paper, and its recommendations to improve the quality of mechanical insulation materials and practices used in BC.

1. What is Mechanical Insulation?

Mechanical insulation (MI) is insulation applied to pipes, ducts, and mechanical equipment (such as boilers, storage tanks, and air handling equipment). It is different from the insulation found in a building’s envelope (‘building envelope’ refers collectively to the walls, basement floor, and roof of a building).

Mechanical insulation is found in both industrial facilities, as well as larger commercial, institutional and residential buildings - typically referred to as ‘Part 3’ buildings (in reference to Part 3 of the BC Building Code). Smaller residential ‘Part 9’ buildings contain minimal or no mechanical insulation systems. This study focuses on mechanical insulation in Part 3 buildings.

2. Why Act to Improve Mechanical Insulation

Improving mechanical insulation is part of the broader effort to improve building performance. Better building performance is critical to forwarding the following priorities:

1. Our health and safety;
2. The economic performance of buildings, including minimizing energy spending and ensuring durable buildings; and
3. Addressing climate change and ensuring sustainable use of energy.

This study investigates the need for action on mechanical insulation design and installation practices in particular to address these priorities. It then suggests ways for the provincial government, local governments, developers, designers, and contractors to improve the quality of mechanical insulation in BC.

3. Promoting Better Building Systems – The Context for Action

The quality and performance of buildings impacts our health, safety, comfort, finances, and environmental impacts, in profound ways. The best building practices can support all these criteria, though occasionally tradeoffs must be made between them. The practice of ‘green building’ or ‘high-performance building’ seeks to optimise a building’s performance across all these criteria and significantly out-perform conventional practice.

This study focuses on the impacts of one building system – mechanical insulation – especially through the lens of energy efficiency and climate protection.

In order to understand why better mechanical insulation practices are important, it is key to understand the context for action in pursuing the priorities listed above.

4. Provincial Climate Policy

British Columbia has some of the most aggressive greenhouse gas reduction targets in the world. Energy efficiency requirements have been increased in the BC Building Code, and much more aggressive changes are anticipated in the near future. Provincial energy and climate change legislation, including the *BC Climate Action Plan*, *Clean Energy Act of 2010* and the *BC Clean Energy Plan*, have set goals and established priorities for reducing energy and emissions through efficiency, and identifies the need to identify economic development strategies, including “green collar jobs” that advance these goals. Mechanical insulators clearly fall into this category.

1. **BC Climate Action Plan** - A major thrust of the Plan was developing a prosperous low carbon economy:
 - “...sets the course for a prosperous, successful and sustainable future in which BC can compete and win in the low-carbon economy.”
 - “...low carbon options are the way of the future.”
2. **Clean Energy Act (2010)** – the following objectives from the *Act* have direct relevance to reducing energy use through better mechanical insulation installation practice and policy:
 - (b) to take demand-side measures and to conserve energy, including the objective of the authority reducing its expected increase in demand for electricity by the year 2020 by at least 66%;
 - g) to reduce BC greenhouse gas emissions

- (i) by 2012 and for each subsequent calendar year to at least 6% less than the level of those emissions in 2007;
 - (ii) by 2016 and for each subsequent calendar year to at least 18% less than the level of those emissions in 2007;
 - (iii) by 2020 and for each subsequent calendar year to at least 33% less than the level of those emissions in 2007;
 - (iv) by 2050 and for each subsequent calendar year to at least 80% less than the level of those emissions in 2007;
 - (i) to encourage communities to reduce greenhouse gas emissions and use energy efficiently; and
 - (k) to encourage economic development and the creation and retention of jobs.
- 3. BC Energy Plan (2007)** – Major energy conservation and efficiency policies in the plan include:
- Set an ambitious conservation target, to acquire 50 per cent of BC Hydro’s incremental resource needs through conservation by 2020;
 - Ensure a coordinated approach to conservation and efficiency is actively pursued in British Columbia;
 - Encourage utilities to pursue cost effective and competitive demand side management opportunities;
 - Implement energy efficiency standards for buildings by 2010;
 - Skills, training and labour as a major thrust of the plan;
 - Government will work with industry to identify trades training requirements for alternative sectors, leading to ITA designations and Red Seals, where appropriate, for example:
 - Work with industry associations to develop new energy efficiency and conservation training, for example, Thermal Energy Comfort Association of BC, Canadian Home Builders Association of BC, to address consumer complaints regarding service standards; and
 - The Ministry will bring key parties together, including associations, employers, entrepreneurs and workers as required, to promote alternative and renewable energy sector networks across BC.

5. Public Sector and Local Government Policy

The Provincial government has also established energy and climate change policy specifically targeted at public sector organisations and local governments. In the case of each of the policies described below, individual and groups of organisations and local governments are taking action and putting in place their own policies to advance climate and energy goals.

- 1. Green Communities Act - Bill 27 (2008)** – Bill 27 amended the Local Government Act and related Acts to address energy and water conservation and GHG reduction.
- Most importantly, new content requirements for official community plans (by 2010) and regional growth strategies (by 2011) include: “...targets for the reduction of GHGs... and policies and actions of the local government proposed with respect to achieving those targets.”
 - There are also provisions to enable Development Permits to address energy conservation, and reduce development cost charges for green developments.

- At the time of writing, the majority of local governments in the province had already adopted or were in the process of creating GHG targets, policies and actions.
- 2. BC Climate Action Charter (2007)** – The BC Government and local governments unveiled the Charter in the fall of 2007. It acknowledges the critical role of communities and the shared provincial-local responsibility in tackling climate change. Adopted by 175+ local governments in the Province, it involves voluntary commitments to:
- Measure and report community GHG emissions;
 - Create complete, compact, energy efficient rural and urban communities; and
 - Become carbon neutral in local government operations by 2012.
- 3. Greenhouse Gas Reduction Targets Act – Bill 44 (2007)** – Bill 44 added legislative rigour to the province-wide targets and GHG reduction objectives inside government operations, specifically:
- Province-wide GHG emissions reduction will be 33% below 2007 levels by 2020 and 80% by 2050; and
 - Public sector organizations, including school districts, health authorities and post secondary institutions, will be carbon neutral by 2010. This can be accomplished through a combination of reducing emissions and purchasing carbon offset credits through the Pacific Carbon Trust.

II. Methods

The methods employed to understand the current state of practice of mechanical insulation installation and the impact of these practices on building energy performance, safety and greenhouse gas emissions consist of the following:

1. **Review of Mechanical Insulation industry journals, reports and publications.** The industry sources were used to summarize the general benefits of MI and problems that can arise when it is not installed properly. Industry publications have also summarised the results from simple energy and economic calculations for MI.
2. **Review of Best Practice Guides, Building Codes, Mechanical Insulation Specifications, and Building Handbooks.** There is not a single standard or best practice guide that is used for MI. This required a broad review (at a high level, rather than a detailed review) of a variety of guides, standards, handbooks and codes in order to understand the specifications that are being incorporated into building design and the practices that are referenced by MI contractors. Refer to the Overview of Standards section later in the document for more detail.
3. **Review of Academic Journal Articles.** Mechanical insulation's coverage in peer-reviewed journals was examined in order to identify findings relating MI's contribution to overall building energy use, greenhouse gas emissions and energy costs.
4. **Modeling Mechanical Insulation Energy, GHG and Cost Savings.** As a means to establish independent estimates of the impact of good and poor MI installation practice on total building energy use, three building typologies—based on three real buildings—were chosen and modeled using the 3E Plus software program. The National Insulation Association (NIA) of the United States developed the 3E Plus3 software to optimize insulation design through energy, environmental and economic analyses. This software has been utilized to analyze the effects pipe insulation on the energy performance of the three chosen building typologies. The three typologies were chosen to represent large format commercial and multi-unit residential buildings where there is the greatest opportunity for improving current practice.
5. **Interviews with professionals in the mechanical insulation industry and related building industry professions.** To qualify the quality of mechanical insulation in new construction, HB Lanarc conducted a key informant survey of various building industry members and stakeholders. Members of the following groups were surveyed:
 - Building officials and inspectors;
 - Mechanical insulation contractors;
 - Mechanical contractors;
 - Mechanical engineers;
 - Mechanical insulation suppliers;
 - Mechanical insulation manufacturers;
 - Building commissioning agents;
 - Developers; and
 - Policy and advocacy leaders.

³ 3E Plus Insulation Thickness Computer Program. http://www.pipeinsulation.org/pages_v4/details.html

- The survey consisted of telephone interviews, typically lasting 15 minutes to 45 minutes. Interviewers worked from a scripted list of questions, but frequently delved into new topics of conversation as interviewees provided insights and opinions. The interviews were designed to:
 - Determine interviewees knowledge of typical mechanical insulation industry practice, and regulatory requirements;
 - Qualify the quality of mechanical insulation systems in new buildings, both in terms of code compliance and best practices in installation;
 - Determine reasons for the level of good practice in the industry; and
 - Determine opportunities to improve practices.

- Notes from the interviews were taken using a word processor on a personal computer and then reviewed and summarized upon completion to ensure accuracy. The list of interviewees was provided to the IAHFIAW, but individual responses have been kept anonymous to protect the identity of the interviewees.

- Input and opinions regarding the state of mechanical insulation practice and recommendations for opportunities to improve practice were also contributed by the authors and members of the Heat and Frost Insulation Union. This input was based on diversity of experiences in the industry that includes conducting MI installations and physical reviews and audits of hundreds of buildings.

III. Current Practice

1. Why is Mechanical Insulation Important?

Mechanical insulation serves a variety of objectives in buildings⁴:

1. Energy conservation – Preventing heat loss or gain from mechanical systems.
2. Condensation control – Preventing the possibility of water damage from condensation on cold pipes.
3. Fire safety – Protecting mechanical systems from fire, and slowing the spread of fire in buildings.
4. Freeze protection – Protecting liquid in pipes from freezing, which could potentially damage pipes.
5. Personnel protection – Controlling surface temperature of mechanical equipment to avoid contact burns.
6. Process control – Minimizing temperature change along mechanical systems (especially important when close control is needed).
7. Noise control – reducing the noise from ducts, pipe and equipment.

The success of mechanical insulation designers and contractors in achieving the above objectives will ultimately impact a building's:

- Energy consumption, associated costs and greenhouse gas emissions;
- Durability; and
- Provisions for human safety and comfort.

2. Ensuring Mechanical Insulation Performance

Ensuring optimal performance of mechanical insulation systems requires good design, proper choice of materials, proper installation, and maintenance. Various standards have been compiled by mechanical insulation trade organizations, to guide designers and contractors in best practices. They include:

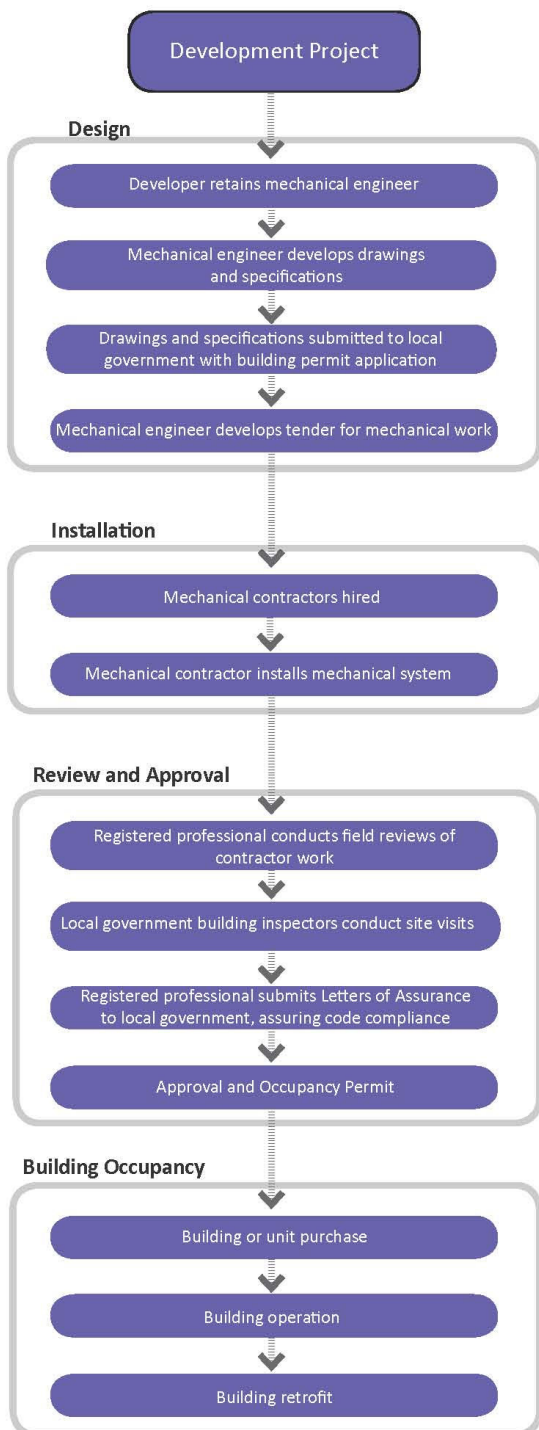
- The BC Insulation Contractors Association's *Quality Standards for Mechanical Insulation (for Commercial and Institutional Buildings)* – Cited in many mechanical engineering specifications in BC and beyond;
- Thermal Insulation Association of Canada – *Mechanical Insulation Best Practices Guide*; and
- Midwest Insulation Contractors Association – Commercial and Industrial Insulation Standards Manual.

A description of the elements of properly designed and installed mechanical insulation systems is beyond the scope of this report – indeed, the standards noted above are hundreds of pages in length. Important elements to ensure proper mechanical insulation include:

⁴ This list derived from: National Mechanical Insulation Committee. June 2010. *Mechanical Insulation Design Guide – Design Objectives*. Whole Building Design Guide. Accessed online July 14th 2010. http://www.wbdg.org/design/midg_design.php

1. Material choices that support mechanical systems design requirements, such as temperature.
2. Appropriate thermal resistance, specifying appropriate R-values to meet Building Code minimum requirements and potentially to further optimize energy performance.
3. Proper installation of mechanical insulation - varying by product and application.

3. Who is Responsible for Mechanical Insulation Best Practices?



The flow chart on the left illustrates a typical process followed during development, as it pertains to mechanical insulation.

Figure 1 – Steps in a development project that involve MI design, installation and review. During each of the four phases (Design, Installation, Review and Approval, and Building Occupancy) there are decisions that need to be made that have a significant impact on the appropriateness, quality and performance of mechanical insulation.

Mechanical Engineers – Design heating and cooling systems, choose the reference standards for mechanical insulation thicknesses and installation practices to follow. They also serve as the “Registered Professional” and review the work performed, signing the “Letters of Assurance” that indicate that the finished work meets BC Building Code requirements.

Mechanical Contracting Firm – Hired by the lead construction contractor to install building heating and cooling systems. The mechanical contractor chooses the firm or individuals that install the mechanical insulation.

Mechanical Insulation Installer – Installs the insulation on pipes, ductwork and mechanical systems associated with building heating and cooling.

Building Official – An employee of local governments who may or may not, at local governments’ discretion, review the design documents, Letters of Assurance and perform field reviews as a part of the building permitting process.

Notable Organisations

- **British Columbia Insulation Contractor's Association** – The British Columbia Insulation Contractor's Association (BCICA) was established to develop and distribute mechanical insulation standards to designers, specifying authorities and users of mechanical insulation systems. Today, the BCICA represents all elements of the insulation industry, including union and non-union contractors, distributors and fabricators, and manufacturers.
 - BCICA's Quality Assurance Guide and Standards – Among professionals in BC and other jurisdictions, this guide and best practices manual serves as the standard for how mechanical insulation should be installed.
- **Thermal Insulation Association of Canada (TIAC)** – The national industry association for contractors, distributors and manufacturers of commercial, industrial and institutional thermal insulation. TIAC is one of the primary organisations that lobbies for better MI standards in the national building and energy codes. TIAC has also published the Mechanical Insulation Best Practices Guide, which is widely referenced by engineers and installers.

4. Regulations, Standards and Enforcement

Energy performance (and consequently GHG emissions) of buildings is primarily determined by regulatory building codes and standards, the extent to which buildings comply with these codes and standards, and the effective use of best practices in design, construction and commissioning.

Building elements that influence energy and GHG emissions performance include building form and passive design elements, envelope thermal performance, efficient lighting and equipment, and efficient heating, ventilation and air conditioning (HVAC) systems. Mechanical insulation is a key part of efficient HVAC systems. Building codes and standards address all these elements to varying extents. Building codes regulate fire protection and safety; mechanical insulation best practices also play an important role in ensuring fire and safety objectives are met.

There is no single standard that addresses all elements of mechanical insulation. Table 2 (below) summarizes the most common codes and standards applying to mechanical insulation in BC, with an indication of the scope of each of these.

A combination of ASHRAE 90.1 or 189.1 standards, relevant ASHRAE handbook content, and the BCICA Quality Standards would provide a reasonably comprehensive and up to date set of standards and guidelines for practice in BC.

Overview of Mechanical Insulation Standards and Guidelines

Table 2 provides a general overview of the codes, standards and guidelines related to mechanical insulation that are most commonly used by designers in BC. Due to the complexity, technical content and large amount of detail in most of these standards, this overview is not comprehensive, nor exhaustive; rather, it is intended to provide a high level comparison of these standards to inform readers who are not intimately involved with mechanical insulation design or standards development. In addition to the standards listed in the table, there are many other standards and guidelines pertaining to mechanical insulation that designers and installers may be consulting. These have not been reviewed, but several examples are included for reference following the table.

Table 2 – Comparison of Mechanical Insulation Standards and Guidelines

Standard	Comments	Installation Best Practices	Insulation Thickness / R-value	Fire Protection	Acoustic Isolation	Personnel Protection
National Building Code 2005⁵	Mandatory provisions for some duct systems.	√ Very limited information on installation practices.	-	√ Specific requirements for flame spread ratings.	-	√ Insulation required where temperatures exceed 120°C.
MNECB 1997	-	-	√ Thickness tables are not consistent with most current standards.	-	-	-
British Columbia Building Code	Mandatory (outside Vancouver).	√ Makes reference to ASHRAE standards.	√ Makes reference to ASHRAE standards.	√√ Specific requirements for flame spread ratings given.	-	√ Insulation required where temperatures exceed 120°C.
City of Vancouver Building By-law, 2007	Mandatory (inside Vancouver). Generally similar to BC Code but may have differences w.r.t MI	Does not adequately address installation practices.	√ Makes reference to ASHRAE standards.	√√ Specific requirements for flame spread ratings given.	-	√
ASHRAE 90.1 2004, 2007, 2010⁶	Referenced by the BC Building Code.	- Does not adequately address installation practices. Does provide some information on selection of materials.	√√ Minimum thicknesses for pipes, ducts.	-	√ Provides very limited information on noise transmission characteristics of some materials. Basic physical parameters are published.	√

Legend:

- √√ Fully addresses
- √ Partially addresses
- Minimally addresses or does not address

⁵ National Building Code of Canada 2005, National Research Council

⁶ ANSI/ASHRAE/IESNA Standard 90.1 2004 and 2007, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.

Standard	Comments	Installation Best Practices	Insulation Thickness / R-value	Fire Protection	Acoustic Isolation	Personnel Protection
ASHRAE 189.1 2009 ⁷	Recently created standard; minimum standards are generally beyond ASHRAE 90.1.	- Does not adequately address installation practices. Does provide some information on selection of materials (with specific reference to environmental impact).	√ Minimum R-value for pipes, ducts and equipment.	-	√ Provides very limited information on noise transmission characteristics of some materials. Basic physical parameters are published.	-
ASHRAE Handbooks – e.g. Fundamentals 2005, Chapter 26	Describes mechanical insulation design and installation considerations and best practices for pipes, ducts, and equipment.	√ Has limited information on installation practices. Does provide limited information on material selection.	-	√ Provides very limited information on flame spread characteristics. Best to obtain this information from supplier or recognized standards agency.	√ Provides very limited information on noise transmission characteristics of some materials. Basic physical parameters are published.	√
BCICA Quality Standards for Mechanical Insulation	Aimed at assisting “in the preparation of commonsense mechanical insulation”, firestopping and smoke seals, asbestos abatement and economy/efficiency. Includes guidance on materials and products.	√√ This is a good resource for installation practices and material selection.	-	√	-	-

Legend:
√√ Fully addresses
√ Partially addresses
- Minimally addresses or does not address

⁷ ANSI/ASHRAE/IESNA Standard 189.1 2009, Standard for the Design of High-Performance Green Buildings, American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc.

Other standards and specifications (or specifications sources) that relate to mechanical insulation include:

- National Master Specification⁸
- Midwest Insulation Contractors Association's Commercial and Industrial Insulation Standards Manual.⁹
- ASTM International
- Canadian Standards Association (CSA)
- National Fire Protection Association
- LEED for New Construction 2009 - a widely used rating system used to certify buildings as meeting "green design" principles; it references both MNECB and ASHRAE 90.1 standards to establish energy performance criteria, without making any reference to mechanical insulation.

1. National Building and Energy Codes of Canada

While the Model National Building, Fire and Plumbing Codes are prepared centrally under the direction of the Canadian Commission on Building and Fire Codes, adoption and enforcement of the Codes are the responsibility of the provincial and territorial authorities having jurisdiction.

The National Building Code of Canada (2005) contains provisions for mechanical insulation. It is the authors' understanding that these code provisions were developed some time ago and do not cover all aspects of mechanical insulation; however the NBC was not reviewed as part of this paper.

The Model National Energy Code of Canada for Buildings (MNECB) 1997 includes minimum pipe insulation thickness tables. However these tables were created many years ago, and more recent standards (such as ASHRAE 90.1 2010) have increased minimum thicknesses. The authors' understanding is that the MNECB authors are currently considering updates to these tables, as part of an MNECB update planned for 2011.

Future Provincial building codes may adopt elements of the National Building Code or MNECB at their discretion; in general (i.e., not specific to mechanical insulation), the BC code is substantially the same as National Model Codes with variations that are primarily additions.¹⁰

2. BC Building Code and Vancouver Building Bylaw

The BC Building Code applies to all construction in BC, except in the City of Vancouver. The City of Vancouver has its own Charter, and its building requirements are contained within the Vancouver Building Bylaw, a document derived from the BC Building Code, with a number of distinct differences, including energy performance requirements.

Both regulations classify buildings into two broad building types:

⁸ Public Works and Government Services Canada. <http://www.tpsgc-pwgsc.gc.ca/biens-property/ddn-nms/index-eng.html>

⁹ Midwest Insulation Contractors Association. <http://www.micainsulation.org/standardsmanual.html>

¹⁰ NRC Model Code Adoption Across Canada. http://www.nationalcodes.ca/eng/code_adoption.shtml

- 'Part 3' construction – includes more complex building types, including most commercial buildings, and multi-unit residential buildings with shared hallways; and
- 'Part 9' construction – includes smaller residential construction.

Mechanical insulation tends to be more important in Part 3 buildings, due to their larger size, complexity and extent of pipes, ducts and HVAC equipment.

Design professionals and owners are responsible for construction of buildings to meet the BC or Vancouver code. For Part 3 buildings, 'Registered Professionals' must complete 'Letters of Assurance', confirming that their design and field reviews have ensured that construction meets code provisions.

In BC, most energy efficiency requirements for Part 3 construction are made by referencing the American Society of Heating, Refrigeration and Air-Condition Engineers (ASHRAE) Standard 90.1 *Energy Standard for Buildings Except Low-Rise Residential Buildings*:

- The BC Building Code references ASHRAE 90.1 2004; and
- The Vancouver Building Code references ASHRAE 90.1 2007, a more recent and slightly more stringent standard from an energy efficiency perspective.

Recently, BC Housing and Construction Standards included reference to these ASHRAE standards in the Letters of Assurance.

3. ASHRAE Standards

ASHRAE 90.1 specifies minimum insulation thickness for different piping and duct applications in different climate zones¹¹; it does not specify minimum insulation for mechanical equipment insulation applications. ASHRAE 90.1 provides some cursory guidance on design objectives, noting that mechanical insulation should be protected from the elements and cited means of doing so¹². However, this instruction alone is not sufficient to ensure energy efficiency, or other objectives such as durability, and ASHRAE specifies that "[Mechanical] Insulation ... shall be installed in accordance with industry-accepted standards"¹³. It refers readers in its Informative References Appendix E to the Midwest Insulation Contractors Association's *Commercial and Industrial Insulation Standards Manual*.

ASHRAE Standard 189.1, a relatively new standard, specifies mechanical insulation thermal resistance (R-values). This standard defines the minimum requirements for a high-performance green building, and may in time supersede ASHRAE 90.1 in terms of building code references.

¹¹ ANSI/ASHRAE/IESNA Standard 90.1-2007. Tables 6.8.2 Duct Insulation Tables and Table 6.8.3 Minimum Pipe Insulation Thickness.

¹² ANSI/ASHRAE/IESNA Standard 90.1-2007. Section 6.4.4 HVAC System Construction and Insulation.

¹³ Ibid.

4. Local Authority over Building Standards

Local governments in BC can enact their own building regulations for the purpose of energy conservation, however this authority (with the current exception of the City of Vancouver) requires approval of the provincial government¹⁴.

5. Local Government Authority to Enforce Codes

The Local Government Act confers upon municipalities the power, but not the obligation, to enforce the BC Building Code¹⁵. Local governments can:

- Issue permits, including development, building, and occupancy permits;
- Conduct building inspections, as part of its permitting regime; and
- Withhold permits, if construction is found to be in violation of the Code.

Local governments define in their building bylaws how they will exercise these powers. Building bylaws differ from jurisdiction to jurisdiction. Many local governments, some spurred by liability concerns, have limited their extent of oversight in construction of Part 3 buildings. In particular, the Municipal Insurance Association of BC's 2002 *Building Bylaw Project* is cited by some building officials (during our interviews) as a driver to reduce or eliminate local government building inspections in Part 3 buildings.

The extent of Building Code enforcement therefore varies across the province. Some local governments undertake more detailed inspections, in addition to the "field review" provided by registered professionals. Some local governments provide more cursory spot checks, to generally confirm Letters of Assurance. Some do not engage in site visits for Part 3 construction.

6. Engineering Specifications

A mechanical insulation engineering specification is an explicit set of requirements for the thickness, type and application of insulation for a project. In preparing a specification, engineers must integrate the BC Building Code requirements with the unique needs of each project. Currently in BC, due in part to the lack of comprehensive national or provincial standards for mechanical insulation, engineering firms typically adopt or create their own standards for mechanical insulation that are based on a diversity of sources. This adds to the inconsistency in mechanical insulation practices across projects.

¹⁴ Jurisdiction Options for Energy Efficiency and Renewable Energy in Buildings, Pembina Institute, May 25, 2010.

¹⁵ For a discussion of the interaction between the Local Government Act and the Building Code, see The Municipal Insurance Association of British Columbia. 2002. *Building Bylaw Project*. http://www.miabc.org/Library/Risk-Management/Building-Liability/Bylaw/dcd17_Building_Bylaw_Project.aspx

IV. Characterizing Mechanical Insulation Issues

1. Overview

Insulation practices for pipes and ductwork systems commonly observed in commercial buildings and industrial facilities throughout British Columbia vary greatly. While standards do exist that adequately define proper selection of materials and best practices for installation as documented earlier, the results noted in our sampling of different residential and commercial buildings shows that these standards are not always met.

As part of this paper, we have undertaken to assess the extent of these impacts – both qualitatively and quantitatively, to the extent practical within the scope of this report. We have also surveyed and summarized some of the available literature.

2. Literature Review

References to the importance of proper duct design, material selection, and insulation can be found in both academic literature and in government policy documents. The International Energy Agency,¹⁶ the US Department of Energy, and various organizations within the European Union, have all published materials regarding the importance of duct insulation in regards to energy efficiency and human health. Key findings and trends from both academic literature and government policy are summarized below; additional information on energy impacts of mechanical insulation practices are summarized in the following section on *Quantifying the Impacts*.

References to the health consequences of poor duct sealing and insulation can be found throughout the literature. Poor duct work has been shown to be problematic in institutional settings with regard to human health. In particular, combinations of dirt and moisture can create mould and contribute to “sick building syndrome.”^{17, 18} Research conducted on schools in the US has found that ductwork is often contaminated, and the findings underline the importance of expertise in both the design and the installation of ductwork:

“If the HVAC system is properly designed, fabricated, installed, operated and maintained, these duct systems pose no greater risk of mold growth than duct systems made of sheet metal or any other materials. However, the very properties that make duct board and duct liner superior insulators (e.g., a fibrous structure with large surface area that creates insulating air pockets), also makes them capable of trapping and retaining moisture if they

¹⁶ J. Lausten, *Energy Efficiency Requirements in Building Codes: Energy Efficiency Policies for New Buildings*, International Energy Agency, 2008, available at http://www.iea.org/g8/2008/Building_Codes.pdf.

¹⁷ D Ahear *et. al.*, Fungal colonization of fiberglass insulation in the air distribution system of a multi-story office building: VOC production and possible relationship to a sick building syndrome, *Journal of Industrial Microbiology & Biotechnology*, V. 16, # 5, pp. 280-285, available at <http://www.springerlink.com/content/g44g372045m38573/>.

¹⁸ T. Malmstrom *et. al.*, *Source Book for Efficient Air Duct Systems in Europe, AIRWAYS Project*, 2003, available at http://www.inive.org/Documents/Airways_source_book.screen.pdf.

do get wet (though the fibers themselves do not absorb moisture). While there is an ongoing debate about the wisdom of using insulation materials in duct systems that might retain moisture longer, all sides agree that extraordinary attention to preventing moisture contamination of the duct work should be the primary strategy for preventing mold growth.”¹⁹

The importance of acoustic insulation for duct work and piping is described primarily within industry magazines (e.g. *Insulation Outlook*). Documented consequences of poor acoustical insulation include reduced cognitive functioning (learning) in children²⁰ and increased stress levels for both employees and patients in hospitals.²¹ Acoustic insulation can therefore be viewed not only as part of building occupant comfort, but also of human health.

Within the European context, improvements in ductwork energy efficiency have received a substantial amount of attention over recent years. The International Network for Information on Ventilation and Energy Performance, a research-based organization in Europe, has released a book focused on efficient air-duct systems in Europe. The document cites a fairly broad acceptance of the importance of duct insulation, and recommends a variety of policy responses and best practices.²² Ductwork was identified as a major source of energy wastage in several Nordic countries over the past several decades, and the primary emphasis of the policy response has been placed on the widespread use of ducts with pre-fitted seals, a response which can increase challenges during the design stage.²³ It is worth noting that five countries in Europe have specific regulations for ductwork “airtightness,” most of which include minimum performance standards. A few countries even have compulsory testing during building commissioning.²⁴ The focus on duct sealing (airtightness) seems appropriate, as most air leakage in ductwork comes from joints, followed by seams, and sealing gaskets can decrease these leakages by half.²⁵

3. Insulation Issues in BC

As noted earlier, the current edition of the BC Building Code does not include specific recommendations for the installation of insulation on pipes, ducts or equipment. Within the code there are requirements for flame spread ratings of insulation as well as requirements for maximum service temperatures on systems, unless protection is in place, but no specific requirements expressly to limit heat transfer,

¹⁹ US Environmental Protection Agency, *IAQ Design Tools for Schools: Heating, Ventilation, and Air Conditioning Systems*, (year) retrieved September 15th 2010 from http://www.epa.gov/iaq/schooldesign/hvac.html#Designing_for_Efficient_Operations_and_Maintenance

²⁰ Ibid.

²¹ F. Babineau, The role of HVAC insulations in healthcare, *HPAC Engineering*, April 1st, 2008, available from http://hvac.com/ventilation-iaq/role_hvac_insulations/.

²² T. Malmstrom *et. al.*, *Source Book for Efficient Air Duct Systems in Europe, AIRWAYS Project*, 2003, available at http://www.inive.org/Documents/Airways_source_book.screen.pdf.

²³ F. Carrié, M. Fleury, and G. Voisin, Stimulating better envelope and ductwork airtightness with the Energy Performance for Buildings Directive, *Centre d’Etudes Techniques de l’Equipement de Lyon*, 2007, available at http://www.asiepi.eu/fileadmin/files/WP5/D5.4c_Paper_3_-_Carrie_-_AIVC_2008_-_Stimulating_better_aitightness.pdf.

²⁴ Ibid.

²⁵ C. Aydin and B. Ozerdem, Air leakage measurement and analysis in duct systems, *Energy and Buildings*, V. 38, I. 3, March 2006, pp. 207-213.

condensation and corrosion of equipment. However the BC Building Code does reference other standards to be used as guidelines such as those developed by ASHRAE.

This lack of regulated mechanical insulation requirements results in a mixed response by local governments, consultants and contractors to the selection and installation of insulation materials. To illustrate some of the issues that occur, we have assembled some sample photographs (with additional photos included in Appendix D) of building systems within BC. We should add that this is by no means a comprehensive representation of the state of construction in BC; instead we are only using the information to illustrate some of the conditions we will discuss in this paper. The photos and observations were collected by Jeff Besant of Besant and Associates Engineers through the course of his work as an engineer on buildings in the lower mainland.

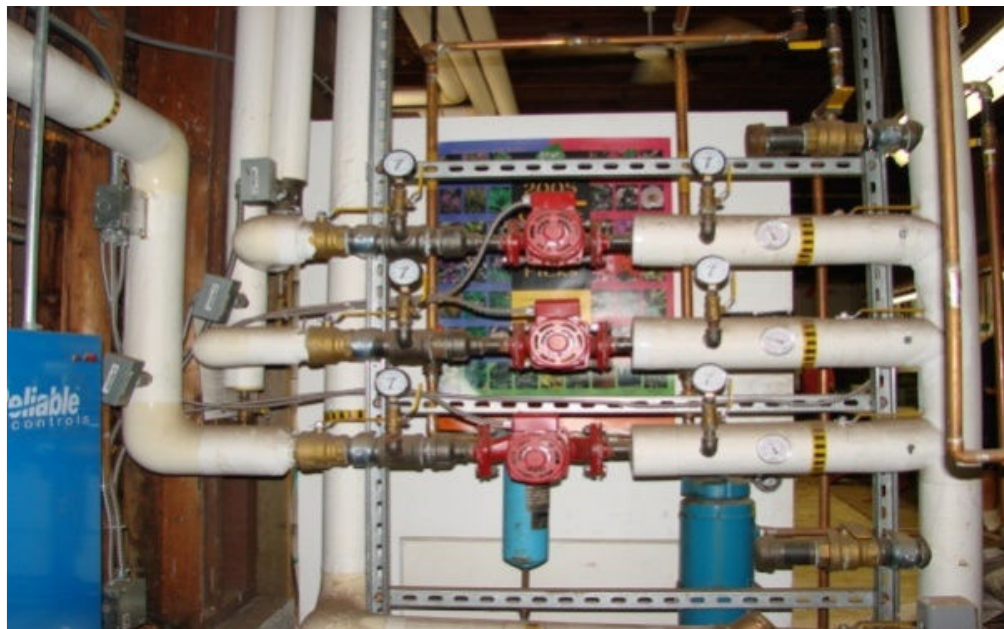


Photo 1 Detail showing circulation pumps on a hydronic distribution system

When installed properly (Photo 1), the service life of the insulation will usually match the service life of the piping, ducts or equipment it is installed on.



Photo 2 Detail showing un-insulated hydronic distribution system and heat exchanger for domestic hot water system

However, it is common to not see insulation (Photo 2) in mechanical rooms and on pipe and duct runs through buildings. Energy is often wasted by transfer into unheated areas that don't need any heat (e.g. mechanical rooms) or pipe chases.



Photo 3 Detail showing backflow preventer on domestic water supply line. Note the water dripping from the device.

It is common to see condensation on un-insulated sections of domestic water piping and fittings. The preceding photo (Photo 3) shows condensation on a backflow preventer. Generally fittings are made of brass or stainless steel and these are not affected by some condensation; however, there will be an increased heat transfer rate due to condensation. Where carbon steel piping or fittings are used, the affects of condensation may be more serious (Photo 4 and 5). Also, condensation can damage building elements such as drywall, ceiling tile and concrete below dripping pipes.



Photo 4 Detail showing corrosion damage to pipe fittings as the result of condensation.



Photo 5 Detail showing heat exchangers used with domestic water system approximately 12 years old. Note the build up of deposits on the heat exchangers.



Photo 6 Detail showing rubber insulation on a hot gas refrigerant line. The insulation should be jacketed to protect it from sun and birds.

Problems with insulation are not limited to whether there is insulation installed or not. Sometimes designers or contractors have made poor choices or have not adequately protected the insulation from environmental damage. The preceding photo (Photo 6) gives an example of rubber closed cell foam insulation that has been attacked by birds. At the time this photo was taken, the insulation was less than one year old. When installed properly, this kind of insulation would have a PVC jacket which prevents damage from pests and from the ultraviolet rays from the sun, extending the insulation service life.

While we have not conducted an exhaustive survey, we have noted examples of air distribution ducting systems that were not insulated in circumstances where insulation would probably make some sense (Photo 7).



Photo 7 Detail showing a section of an un-insulated supply air duct on a roof mounted make-up air unit.

The following table summarizes the common deficiencies we have identified, along with a more detailed explanation of the impacts of these deficiencies.

Table 3 – Common Mechanical Insulation Deficiencies and their Impacts

Deficiency	Effects or Impacts
No insulation (either not installed, or removed by maintenance contractors)	Excessive heat transfer
	Pipe or duct deterioration due to corrosion
	Risk of injury, e.g. from burns or sharp corners
	Condensation will increase heat rates and may damage building structures
	Energy efficient systems may not perform as specified
Improper installation	Same as above
Insulation removed by maintenance contractors	Same as above
No mechanical protection for insulation	Insulation removed by pests or damaged by the environment
	Vandalism damage to insulation
Improper selection of materials for insulation	Damage to insulation due to heat, corrosion or physical abrasion
	Excessive heat transfer and potential damage to the insulation
	Energy efficient systems may not perform as specified

1. **Excessive heat transfer** will result from not using enough or the wrong type of insulation, wasting energy. In the case of heating systems, the energy will be lost to the surrounding environment and in the case of cooling systems there may be heat gain which will reduce the overall efficiency of the system. However, in the case of advanced building systems where small changes in temperatures occur between the supply and return sections, excessive heat transfer may undermine the effectiveness of the system. This could potentially occur in heat recovery ventilators or with radiant heating and cooling systems.
2. **Pipe or duct corrosion** is common where the system is not protected from condensation or the environment. This will shorten the service life of the equipment. Since the cost of insulation is generally considerably less than the cost of piping or ducting it is preferable to protect the equipment wherever possible.
3. **Risk of injury** refers to the possibility of people being burned with high temperature systems such as steam piping and the risk of injury resulting from coming in contact with a pipe or duct that is not protected with appropriate insulation. Injuries may also be sustained from contact with sharp corners, which can also be mitigated with proper insulation.
4. **Condensation** can not only contribute to corrosion as mentioned previously but can also damage building elements such as concrete, ceiling tiles, drywall and wooden elements. It will also increase heat transfer rates due to latent heat of vaporization.
5. **Energy system performance problems** are a particular concern for high performance/high efficiency systems, as they often operate with very small temperature differences and are especially vulnerable to problems with excessive heat transfer. If the designers have assumed a fluid or gas are being moved through a system adiabatically (i.e., no heat transfer) and there is considerable unintended heat transfer taking place, system performance could be seriously affected.
6. **Mechanical protection** is essential with some insulation systems. The mechanical protection can consist of metal wrapping, PVC wrapping and possibly a canvas wrap. Without the proper application of mechanical protection, the service life and value of the insulation may be considerably reduced.

V. Industry Survey

While industry literature suggests that there is non-compliance with Code and best practices, a broader survey was required to better understand the extent of the problem. To qualify the quality of mechanical insulation in new construction, HB Lanarc conducted a key informant survey of various building and mechanical insulation industry members and stakeholders.

1. Summary of Findings and Responses

The following is a summary of the findings from the interviews. A more detailed version appears in Appendix B.

While industry literature suggests that there is significant non-compliance with building codes and best practices, a broader survey of various building industry members and stakeholders indicated that:

- Oversight of mechanical insulation design and installation by local government building departments is very limited, and varies significantly across BC; and
- There is frequent non-compliance with the BC Building Code. Estimates vary within local governments of the rate of non-compliance with aspects of the code, however municipal building officials interviewed cite frequent code violations of some form or another.

The reasons for poor practice in the industry (identified during interviews) are numerous, and include:

- Outdated or incomplete engineering specifications, or lack of knowledge of best practices by engineers, especially for newer, high performance and low-temperature systems;
- Problems due to unqualified installers and inadequate training;
- Lowest cost tendering and “value engineering,” reducing costs below what is necessary for best practices, particularly when the developer is not the eventual owner or operator;
- A perception among some developers and engineers that mechanical insulation is not a critical building component. This may be due in part to lack of educational focus on this issue;
- Poor quality, lower cost insulation materials on the market;
- Challenges related to engineering field review, including assessing whether installations meet code and design specifications;
- A fragmented design and construction process where engineers and installers do not typically work closely together; and
- Tight construction timelines and focus on drywall completion, which can prevent inspection of some systems.

“The installation and inspection system currently lacks checks and balances. The incentives to cut corners out-weigh the costs from the perspective of the installers and the mechanical engineers...”

There is bragging among contractors as to who can get away with the most regarding cutting corners and doing work that is not performed to specifications.”
– Mechanical Insulation Contractor

“Insulators used to be a part of the plumbers union; then the two groups separated. Since then, the knowledge of good insulation practice among plumbers has gradually decreased. And in order to save costs, developers employ the plumbers to do their own insulation.”

– Mechanical Insulation Supplier

“Dry-wall contractors have the most power on site among the trades. For high-rise buildings, the scheduling is often so tight that the time between the plumbing and dry-walling is a day or two. The insulator does not have time to the job properly. It is not uncommon for the drywall to be installed on the weekend, at a time when the engineer is not working and has not had an opportunity to inspect the mechanical insulation.

– Mechanical Insulation Supplier

“The engineers that inspect the work do not know what constitutes best practice. If they do, they are rarely able to tell when an installation has occurred that does not meet the specifications.”

– Local Building Code Inspector

“Tendering processes overwhelmingly select the lowest bidder, and sometimes the budget is not sufficient for good work to be performed. ‘Value engineering’ is a regular problem, where engineers are asked by developers to reduce the costs associated with installations.”

– Mechanical Insulation Contractor

2. Conclusions drawn from the Interviews

A number of the individuals interviewed had specific recommendations or identified opportunities for improving design and practice in the industry. These include:

- **Educate Engineers and Developers on the Importance of Good Mechanical Insulation** – Use the results from building energy modeling conducted as a part of this report, with the possible combination of additional studies to prepare simple guidelines targeted at engineers and developers that discuss the energy, fire safety and mechanical system longevity implications of good and poor insulation practices.
- **Educate Developers About the Value of Good Mechanical Insulation Practice for the Future Owners of their Buildings** – Just as the development community is beginning to recognise the value of green building and energy efficient building practices in their multi-family housing projects—as a result of market demand and an increasingly educated pool of potential home buyers—this recognition could expand to avoided maintenance costs and improved energy performance as a result of certified good insulation practice. In the Lower Mainland of BC where the general public has seen periodic news stories that highlight the expensive effects of poor building practices—such as leaky condos—a potential buyer is likely to see the value in a system that brings a level of assurance to construction standards.
- **Research and Education on Mechanical Insulation Best Practices for Low Temperature Systems** – A small number of insulation contractors and suppliers in BC have experience with low temperature heating and cooling mechanical systems. The knowledge of these contractors and suppliers should be captured in order to create a best practices guide that can be distributed among mechanical engineers, insulation contractors and developers.
- **Third Party Inspection System to Verify Good Practice** – Engineers and contractors mentioned the need for an independent verification system and body to inspect mechanical insulation work. The creation of such a system, while far from simple, could be implemented with fewer obstacles than expanding the scope of work of building inspectors to include mechanical insulation. Two keys to successfully implementing a third party inspection system that were identified by interviewees were:
 - 1) a training and certification program for the verifiers that ensures proper qualifications for performing the inspections; and
 - 2) promotion and endorsement of the program by industry associations, the provincial government and local governments in order to create sufficient market demand for the verification service.

VI. Quantifying the Impacts

At the outset of this project, the authors identified the usefulness of being able to estimate the impact that mechanical insulation can have on building performance, including energy consumption, greenhouse gas emissions and costs. This is a challenging undertaking, given the wide range of factors and uncertainties that would influence these impacts, including:

- The enormous range of building mechanical system designs and operating conditions;
- The extent of components within these systems appropriate for mechanical insulation; and
- The difficulty in estimating the performance effects of mechanical insulation deficiencies, particularly those that are due to improper installation practices.

However, in this section we are able to illustrate the potential impacts of mechanical insulation issues through some basic building energy modeling and analysis, with a brief survey of studies from literature.

1. Case Studies from Literature

Within the US, a substantial number of articles during the early and mid 1990s demonstrated the importance of energy loss from residential duct systems. Based on this research, the US Department of Energy has estimated that around one third (30 - 40%) of thermal energy delivered through ducts is lost through leakage and conduction through duct walls.²⁶ Retrofits (sealing and insulation) were able to reduce leakage by approximately 64% and reduced conduction losses by 33%, cutting energy losses in half. A more recent Department of Energy publication states that 20% of energy is lost in these manners when heating and cooling are taken into account.²⁷ A report focused on commercial buildings included similar findings and implications.²⁸ However, policy responses to effect change in the US remain limited.

A study of 42 sample buildings in France and Belgium found that duct leakage was three times greater than permitted within the EUROVENT²⁹ standard applicable to these building types.³⁰ Based on these findings, the potential Europe-wide energy savings from better duct sealing and insulation was estimated at 10,000 GWh (10 TWh) within 10 years.

²⁶ D. Jump and M. Modera, Energy impacts of attic duct retrofits in Sacramento houses, August 1994, Energy & Environment Division, US Department of Energy, available at <http://www.osti.gov/energycitations/servlets/purl/34375-HXiLcQ/webviewable/34375.pdf>.

²⁷ US Department of Energy, *Retrofit Best Practices Guide: How to Save Energy When You Fix Up the Outside of Your Not-So-New House*, January 6th, 2004, available at <http://www.ornl.gov/sci/roofs+walls/facts/RetrofitBestPractices/homeownerguide15b1.pdf>.

²⁸ T. Xu, F. Carrié, D. Dickerhoff, W. Fisk, J. McWilliams, D. Wang and M. Modera, Performance of thermal distribution systems in large commercial buildings, *Energy and Buildings*, V. 34, I. 3, March 2002, pp. 215-226.

²⁹ <http://www.eurovent-certification.com/>

³⁰ R. Carrié *et. al.*, Duct leakage in European buildings: Status and perspectives, *Energy and Buildings*, V. 32, I. 3, September 2000, pp. 235-243.

Several studies have estimated the impacts of improvements in mechanical insulation on residential buildings. Studies conducted on homes in California found that poor sealing was the primary cause of energy loss in space heating³¹ and cooling³² applications, although heat transfer from the ducts as a whole also played a substantial role. The space heating study found that on average 20% of furnace heating energy was lost through un-insulated duct conduction alone.

An industrial case-study at a US Plywood mill demonstrated substantial benefits of piping insulation. Since construction in 1979, the Georgia-Pacific mill had used un-insulated steam lines for its wood-dryer. Retrofits carried out in the late 1990s were able to save approximately 6,000 lbs of steam per hour, equivalent to 18 tonnes of fuel/day. In addition, the insulation increases personal safety by reducing the surface temperature of the pipes.³³

Based on our limited review of available literature, issues related to duct insulation are much better defined in the literature than those focused on water piping or mechanical equipment insulation. As outlined in the following sections, simple energy and cost modeling was undertaken with the goals of estimating some of the impacts of deficiencies observed in the BC context.

2. Modeled, Hypothetical Case Studies

The case studies modeled in this section focus primarily on hot water piping insulation, and compare performance with and without insulation. While our evidence suggests lack of insulation is occurring in new construction, the modeling represents in effect a worst case scenario, in that it is our understanding that in most new construction, water pipes are being insulated (subject to some other deficiencies as documented earlier). Note that images represent the typical building form, rather than the actual building studied.

Insulation Optimization Software

The National Insulation Association (NIA) of the United States has developed software (“3E Plus”)³⁴ that can be used to optimize insulation design through energy, environmental and economic analyses. This software has been utilized to analyze the effects pipe insulation on the performance of the building.

³¹ M. Modera, Characterizing the performance of residential air distribution systems, *Energy and Buildings*, V. 20, I. 1, 1993, pp. 65-75.

³² D. Parker, P. Fairey, & L. Gu, Simulation of the effects of duct leakage and heat transfer on residential space-cooling energy use, 1991, *Energy and Buildings*, V. 20, I. 2, pp. 97-113.

³³ Georgia-Pacific reaps benefits by insulating its steam lines, *Insulation Outlook*, March 1998, available at <http://www.insulationoutlook.com/io/article.cfm?id=IO980303>.

³⁴ 3E Plus Insulation Thickness Computer Program.
http://www.pipeinsulation.org/pages_v4/details.html

1. Case Study 1: Four Storey Wood Frame Apartment Building, 20-40 years old



In this case study we analyze the effect of insulation on the performance of mechanical systems in buildings. For this example, we have used a four storey wood frame multi-unit residential building, a building type common in the BC Lower Mainland and many other jurisdictions, with un-insulated domestic hot water copper piping to estimate the payback resulting from different insulation strategies. In this case, the heat flux from the domestic water piping contributes to the space heating for the winter months. In the summer months however, the energy is wasted because the additional heat is not required. There is a re-circulation pump on the system, which is controlled by an aquastat, so that the supply and return temperatures remain relatively constant.

Assumptions:

- Leaving water temperature (LWT) = 60°C
- Entering water temperature (EWT) = 50°C
- Heat source: direct fired gas water heaters with a nameplate efficiency of 80%
- Indoor design temperature: 20°C
- Heating season: September 15 to May 15 (8 months)
- Gas cost: \$9.486/GJ
- Service life: 20 years
- Building conditioned floor space: approx. 45,000 square feet (4,200 square metres)

Table 4 - Approximate lengths and heat flux of domestic water hot water distribution piping (based on building drawings)

Pipe diameter (mm)	Approximate Length (m)	“q” (W) no insulation	“q” (W) with 25 mm insulation
20	100	2,639	607
25	25	801	158
40	25	1,108	205
50	20	1,082	192

Over the course of one year the following savings would result from the use of insulation.

Table 5 - Annual Energy and Greenhouse Gas Savings

Resource	Annual Reduction
Energy Saved (kWh)	45,802
GHG Emissions CO2e (tonnes)	8.4

The following table summarizes the impact on overall building energy consumption.

Table 6 - Contribution to Overall Building Energy Consumption

Floor space	4,200 m ²
Typical energy intensity (Lower Mainland)	173 kWh/m ² /year
Total energy consumption	726,600 kWh
Energy savings due to pipe insulation	45,802 kWh, or 6.3% of total consumption

The estimated payback for the investment in insulation during construction would be less than 4.0 years based solely on the energy costs.

2. Case Study 2 – 25 Storey Residential Tower, 10-20 years old



As an example, we have used a 25 storey high rise residential tower with un-insulated domestic hot water copper piping to estimate the payback resulting from different insulation strategies. The building is electrically heated and the domestic water piping within the mechanical rooms is insulated. Only the piping in the pipe chases is not insulated. There is a re-circulation pump on the system, which is controlled by an aquastat, so that the supply and return temperatures remain relatively constant.

The building has a high and low zone each served from the domestic hot water heaters mounted in a roof top mechanical room. There are eight risers in each of the zones (high and low) and there is a 150 mm diameter line supplying hot water from the mechanical room to the lower zone (approximately 36 meters below the mechanical room).

Assumptions:

- Leaving water temperature = 60°C
- Entering water temperature = 50°C
- Heat source: direct fired gas water heaters with a nameplate efficiency of 80%
- Indoor design temperature: 20°C
- Gas cost: \$9.846/GJ
- Service life: 20 years for the domestic water piping

Table 7 - Approximate lengths of domestic water hot water distribution piping (based on building drawings)

Pipe diameter (mm)	Approximate Length (m)
25	115
40	45
50	130
65	290
150	36

Table 8 - Heat Flux from Domestic Water Pipes

Pipe dia. (mm)	“q” (W) no insulation	Insulation Thickness	“q” (W) with insulation
25	3,684	25	725
40	1,994	25	369
50	7,036	25	1,247
65	18,662	40	2,218
150	5,018	40	607

With insulation, the power savings would be over 30 kW.

Over the course of one year the following savings would result from the use of insulation.

Table 9 - Annual Energy and Greenhouse Gas Savings

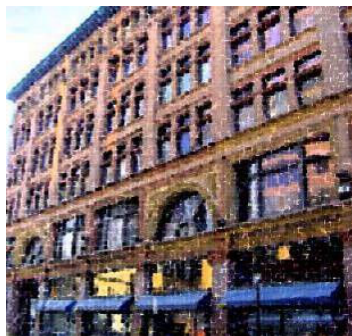
Resource	Annual Reduction
Energy Saved (kWh)	320,085
GHG Emissions CO2e (tonnes)	58.8

Table 10 - Contribution to Overall Building Energy Consumption

Floor space	13,000 m ²
Typical energy intensity (Lower Mainland)	173 kWh/m ² /year
Total energy consumption	2,249,000 kWh
Energy savings due to pipe insulation	320,085 kWh, or 14.2% of total consumption

The estimated payback for the investment in insulation during construction would be less than 2.7 years based purely on the energy costs.

3. Case Study 3 – Large Retail Store, > 45 years old



As an example, we have used a six storey large commercial/retail tower (approximately 60,000 square metres) with un-insulated domestic steam seamless ERW steel pipe and ductile iron chilled water piping. The heat source is a central steam plant located off-site from the building. The steam is delivered at low pressures and the peak demand is approximately 4,000 kg/hr. There are approximately 600 tons of cooling mounted in roof level mechanical room. Both the steam and chilled water piping was originally insulated however over time the insulation has been removed by contractors and has deteriorated over time. There is limited domestic water piping and we have not included this in our analysis since a majority of the domestic hot water piping is less than 1 inch (25 mm) in diameter.

We have attempted to estimate the length of pipe where the insulation has deteriorated to the point where it has to be replaced for both the steam heating system and the chilled water systems.

Assumptions

- Chilled water leaving temperature = 10°C
- Chilled water entering temperature = 16°C
- Steam system provides saturated steam at 10 psi
- Heat source: central steam system located offsite (we have assumed the efficiency of the steam plant is 80%)
- Indoor design temperature: 23°C
- Gas cost: \$9.846/GJ
- Electricity Cost: \$0.0691/kwh
- For the purposes of this analysis we have assumed both systems operate for approximately 4,000 hours per year
- Remaining service life: 30 years for the both the steam and chilled water piping

The following tables show approximate lengths of distribution piping (based on building drawings) which requires new insulation.

Table 11 - Steam Piping

Pipe diameter (mm)	Approximate Length (m)
50	100
150	150

Table 12 - Chilled Water piping

Pipe diameter (mm)	Approximate Length (m)
50	700
80	650
150	30
200	45

The following tables show Heat Flux from Heating and Cooling Piping Systems.

Table 13 - Steam Piping

Pipe dia. (mm)	“q” (kW) no insulation	Insulation Thickness	“q” (W) with insulation
50	23,049	50	20,206
1500	90,714	50	6,398

Table 14 - Chilled Water Piping

Pipe dia. (mm)	“q” (kW) no insulation	Insulation Thickness	“q” (kW) with insulation
50	5,764	25	1,059
80	7,634	25	1,335
150	640	25	109
200	1,233	25	195

Over the course of one year the following savings would result from the use of insulation.

Table 15 - Annual Energy and Greenhouse Gas Savings Combined

Resource	Annual Reduction
Energy Saved (kWh)	475,921
GHG Emissions CO2e (tonnes)	81.8

Table 16 - Contribution to Overall Building Energy Consumption

Floor space	60,000 m ²
Typical energy intensity (Lower Mainland)	550 kWh/m ² /year
Total energy consumption	33,000,000 kWh
Energy savings due to pipe insulation	475,921 kWh, or 1.4% of total consumption

The estimated payback for the investment in insulation would be less than six months for the steam system and over five years for the chilled water system.

Modeled Case Studies Conclusions

The primary explanatory variables that explain the difference in energy savings among the three case studies are the size of the heating and cooling system, the length of the exposed pipes and the temperature at which the system operates. Large systems that operate at high temperatures (steam systems) stand to yield the most energy savings and GHG reductions from better insulation. The modeling results also demonstrate that there is a strong case to make for adding insulation to most heating systems, with short payback periods and tangible energy reductions.

3. Other Case Studies

The Thermal Insulation Association of Canada (TIAC), in its discussions with the Canadian Code Centre on the upcoming National Energy Code for Buildings (NECB) 2011, has conducted pipe insulation economic analyses, which calculate simple paybacks for increasing pipe insulation thicknesses from MNECB-1997 minimums to thicknesses proposed by TIAC for inclusion in NECB-2011. The 3EPlus program was used to estimate heat loss and gain within this analysis. Resulting paybacks vary depending on many factors such as operating temperature, pipe diameter, and whether piping is in conditioned or unconditioned space. However simple paybacks associated with **increasing** pipe insulation to currently proposed values for many scenarios range from about 3 to 10 years. This research suggests that there is a significant economic rationale to updating the MNECB-1997 minimum insulation tables, and to generally ensuring sufficient insulation thicknesses are implemented; existing minimum insulation thickness tables do not always result in the best economic performance.

4. Province-Wide Energy, Cost and GHG Estimates

The hypothetical case studies above and the literature reviewed in other sections of this report provide snapshots of the energy savings and greenhouse gas emission reductions that are possible for a single building. The appropriate data is not available to be able to *accurately* calculate the potential savings

and reductions at the level of the entire province. However, findings from the interviews with industry professionals and data and forecasts on energy use from the province and utility companies provide a basis for making *estimates*. The two biggest “unknowns” are the percentage of buildings with mechanical insulation deficiencies and the range in energy performance impact of the deficiencies (which would require energy audits of a representative sample of buildings). Data from the hypothetical case studies and the interviews can be used as a proxy.

Table 17 and Table 18, below, include data, assumptions and calculations for existing BC multi-unit residential and commercial buildings—those that are most affected by mechanical insulation deficiencies. The calculation results in the last three rows of

Table 17 show that if all of the buildings with deficiencies were retrofitted, energy use in the province would be reduced by 280 GWh annually, resulting in \$9.7 million in savings and a reduction in 50,000 tonnes of CO₂ emissions. This is equivalent to the energy use of 7,800 single family houses, or the greenhouse gas emissions from 12,500 cars each traveling 20,000 kilometres.

Another set of rough calculations that provide insight into the magnitude of the opportunity for improving mechanical insulation practice involves new buildings that will be constructed over the next 10 years. Over the next 10 years it is projected that there will be approximately 210,000 additional multi-family residential units built in BC.³⁵ The additional energy demand in 2020 from these units will be approximately 2,000 GWh, based on conservative assumptions about energy intensity and size of the unit.³⁶ If the current trend of poor mechanical installation practice and standards is reversed through policy, financial incentives and building code changes, then potential annual energy savings will be in the range of 60 – 120 GWh or 10,000 to 20,000 tonnes CO₂ (see Table 19 below).

As a means of comparison, Terasen Gas's 2010 Long Term Resource Plan describes annual province-wide Energy Efficiency and Conservation Program investments of \$4 - \$80 million for 20 years in order to reduce natural gas use by 165 – 3,375 GWh each year.

³⁵ BC Stats 2010

³⁶ Average energy intensity of 120 kWh/m², based on steady changes to the BC Building Codes and historical rates for building retrofits. Mean unit size of 80 m².

Table 17 – British Columbia Mechanical Insulation Energy, Cost and GHG Reduction Estimates for Existing Buildings

	Apartment ≥ 5 storeys	Apartment ≤ 5 storeys	Total Multi-Unit Residential Buildings	Commercial Buildings	Total All Buildings
Units in BC (2006) ³⁷	117,590	338,690	456,280	214,982	671,262
% of total ³⁸	7%	21%			
Average Est. Energy Intensity (kWh/m²) ³⁹	173	173			
Average Size (m²) ⁴⁰	87	75			
Total 2007 Energy Use (GWh) ⁴¹	1,770	4,395	6,164	34,838	41,002
Total 2007 Est. Natural Gas Use (GWh) ⁴²	970	2,400	3,400		
Total CO₂e (tonnes) ⁴³	194,860	483,835	678,695	3,439,000	4,117,695
Energy Use (GWh) of Buildings Affected by MI Deficiencies (33%) ⁴⁴	590	1,465	2,055	11,497	13,552
Annual Energy Saving through Retrofit (GWh): 10% for residential, 1.4% for commercial ⁴⁵	59	146	205	75	280
Annual Cost Savings (Natural Gas = \$0.034/kWh) ⁴⁶	\$ 2,005,827	\$ 4,980,436	\$ 6,986,263	\$ 2,798,981	\$ 9,785,244
Potential Annual GHG Emission Reductions (Tonnes CO₂e) ⁴⁷	10,831	26,894	37,726	12,846	50,572

Table 18 – Existing Buildings - Range of Energy and GHG Reductions Possible Through Retrofitting

Percentage of Existing Residential and Commercial Buildings Affected	Annual Energy Saving Possible if Retrofitted (GWh)	Annual GHG Reductions (tonnes CO ₂ e)
20%	170	31,156
33%	280	51,408
40%	339	62,313
50%	424	77,891
60%	509	93,469

³⁷ BC Climate Action Secretariat 2010. Community Energy and Emission Inventory Reports.
<http://www.env.gov.bc.ca/cas/mitigation/ceei/reports.html#N>

³⁸ Ibid

³⁹ Natural Resources Canada 2008. EnerGuide Home Energy Audit Data for British Columbia.

⁴⁰ Ibid

⁴¹ BC Climate Action Secretariat 2010. Community Energy and Emission Inventory Reports.
<http://www.env.gov.bc.ca/cas/mitigation/ceei/reports.html#N>

⁴² Ibid

⁴³ Ibid

⁴⁴ Conservative assumption based on the range of results from interviews with industry.

⁴⁵ Percentages based on modeled hypothetical case studies.

⁴⁶ Calculated value based on natural gas cost savings.

⁴⁷ Calculated number based on reduction in natural gas use.

Table 19 – Residential Buildings in 2020 - Range of Range of Energy and GHG Reductions Possible Through Improving Mechanical Insulation Practice

Percentage of New Multi-unit Residential Buildings Affected	Energy Savings in 2020 (GWh)	GHG Reductions in 2020 (tonnes CO ₂ e)
20%	41	7,455
33%	67	12,301
40%	81	14,911
50%	102	18,638
60%	122	22,366

Discussion and Conclusions

The three BC hypothetical case studies we have modeled to date indicate that energy savings associated with pipe insulation can account for a significant proportion of overall building energy consumption, ranging from just under 1% to 14% for these examples. This suggests that without proper mechanical insulation, buildings are consuming significantly more energy, and producing more GHG emissions, than necessary.

Based on our simple economic analysis that looks at installed costs, maintenance and energy saved, as well as other studies, the costs of providing mechanical insulation to water pipes, in appropriate contexts, will be recovered quickly: generally within several years, in some cases less and in some cases more – but typically meeting developer criteria for payback. A more rigorous analysis could also potentially take into account the impacts of specific insulation deficiencies, such as reductions in equipment service life due to corrosion from condensation; this would further strengthen the case for insulation best practices from an economic perspective.

Taking a broader view, cost implications of insulation issues and deficiencies can extend to mechanical system failures, which can have dramatic capital and maintenance cost impacts; insulation, when properly applied, will prolong the service life of equipment, pipes, ducts and the building.

In the present era of government policies and regulations that encourage or require green building, increasing energy efficiency and decreasing GHG emissions, building designers must strive harder and harder to achieve the higher performance levels required. This is necessitating new design practices and technology such as more efficient mechanical equipment, alternative energy systems such as heat pumps, advanced control systems, waste heat recovery, and better control of air leakage. A comprehensive, integrated design process that considers all design options is necessary to get the best possible performance with the least investment. **Failing to implement mechanical insulation best practices puts building performance at risk.** This not only has implications for achieving GHG emissions reduction targets in BC, but can potentially undermine green building efforts by creating counter-examples where poor performance is used as a reason to discredit green building.

Unfortunately, though the case for insulating equipment, pipes and ducts is sound, there remain many deficiencies in buildings and facilities throughout (and likely outside) BC’s Lower Mainland. The deficiencies range from simply not installing insulation where it is needed, to making poor choices for

insulation and protective coatings and to allowing the insulation to deteriorate or be removed over time.

Despite the obvious importance of mechanical insulation in many types of industrial facilities, discussions with the IAHFIAW suggests that in general, mechanical insulation deficiencies are less common in industrial facilities than in larger commercial and residential multi-family buildings. For this reason, the fact that the latter group accounts for a larger proportion of new development, and that local governments have less influence over large industrial facilities, recommendations made in this report focus on (but are not restricted to) the commercial and residential sectors.

VII. Recommendations

1. Summary of Barriers and Opportunities

The research and analysis bring forward several major areas of concern related to mechanical insulation practices in BC, including:

- Improving BC's ability to achieve provincial and local government energy and emissions targets in the buildings sector;
- Ensuring health and safety objectives are met; and
- Maximizing building and equipment longevity, and minimizing economic impacts including ongoing energy costs.

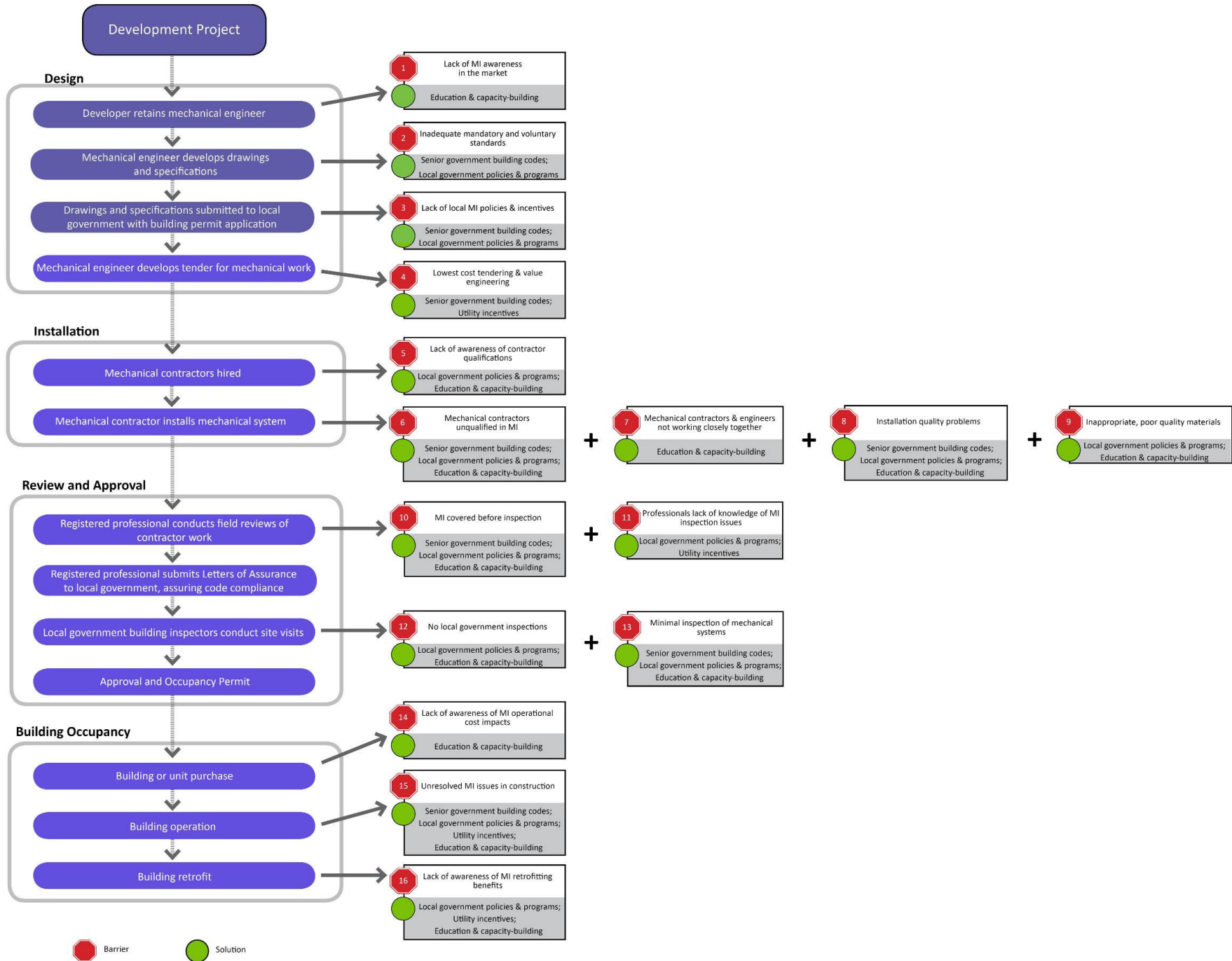
The barriers and identified opportunities are summarised in the following table and figure. These reflect the results from the three major avenues of investigation that were a part of this study: literature review, building energy modeling and interviews with industry professionals.

Table 20 – Summary of Barriers and Opportunities Identified

	Process	Barrier	Opportunities
Design	Developer retains mechanical engineer	(1) Both developer and mechanical engineer may not be fully aware of MI issues	Education and Capacity Building
	Mechanical engineer develops drawings and specifications	(2) There is no single standard in BC covering all three of: practice, materials and thickness. Some of the standards are outdated and specify inadequate fire stopping and insulating value. National Building Code and National Energy Code lag behind most up to date standards.	Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation
	Drawings and specifications submitted to local govt with building permit application	(3) No incentives or policies for MI at the local government level	Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation
	Mechanical engineer develops tender for mechanical work	(4) Because of pressure to cut costs, the estimates can be less than is required to perform the work that is specified; or the original specifications are altered to decrease insulation thickness, or eliminate insulation from "non-critical" components.	BCICA's Quality Assurance Program (under development) Education and Capacity Building Utility Incentives: Utility managed financial incentive program for energy conservation that includes MI
Installation	Mechanical contractors hired	(5) Lack of awareness of contractor qualifications	Local Gov Policy: Adopt a best practice checklist for mechanical insulation Education and Capacity Building
	Mechanical contractor installs mechanical system	(6) Mechanical contractors may lack MI expertise & knowledge; to save money, the lead contractor sometimes hires the plumbing contractor or uses an apprentice to install the mechanical insulation.	Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation Education and Capacity Building
		(7) Mechanical contractors and engineers may not work closely together	Education and Capacity Building
		(8) If a non-union, unqualified MI installer does the job, the fit and finish of the installation is often poor and specifications not carefully followed	BCICA's Quality Assurance Program (under development) Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation Education and Capacity Building
	(9) Low quality insulation materials are used as a cost cutting measure	BCICA's Quality Assurance Program (under development) Education and Capacity Building	
Review and Approval	Registered professional conducts field reviews of contractor work	(10) Scheduling and time pressure result in mechanical insulation getting installed and walls sealed before the Registered Professional can perform an inspection.	BCICA's Quality Assurance Program (under development) Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation Education and Capacity Building
		(11) The Registered Professional may not be knowledgeable about what the installed insulation should look like, nor do they have an eye that is trained enough to be able to distinguish between 1" versus 1.5" insulation, for example.	Education and Capacity Building BCICA's Quality Assurance Program (under development)

	Process	Barrier	Opportunities
	Registered professional submits Letters of Assurance to local government, assuring code compliance		
	Local government building inspectors conduct site visits	(12) Few building inspectors conduct actual site visits.	Education and Capacity Building BCICA's Quality Assurance Program (under development)
		(13) Building inspectors are often not inspecting mechanical systems, and lack the knowledge to effectively do this	Sr Gov Policy: Update the BC Building Code and National Building and Energy Codes Local Gov Policy: Adopt a best practice checklist for mechanical insulation Education and Capacity Building
	Approval and Occupancy Permit		
Building Occupancy	Building or unit purchase	(14) Building owner or operator unaware of the importance of MI issues in long term building operation and costs	Education and Capacity Building
	Building operation	(15) Poor MI in construction results in increased maintenance and operation costs	All Solutions
	Building Retrofit	(16) Building owners, operators unaware of the cost savings, IRR, and simple payback associated with improving mechanical insulation; First-cost orientation	Education and Capacity Building Utility Incentives: Utility managed financial incentive program for energy conservation that includes MI

Figure 2 – Summary of Barriers and Opportunities for Improving Building Energy Performance and Reducing GHG Emissions through Mechanical Insulation



As outlined in previous sections, the reasons for insulation deficiencies are complex and interrelated; a single solution, such as regulatory changes alone, will probably not result in the best possible outcomes. To address these issues, two mutually reinforcing strategic elements are therefore recommended:

- 1. Provide a consistent regulatory framework across BC that embeds standards for mechanical insulation in building codes; and**
- 2. Build capacity in local government and industry (i.e., development and construction) to maximize compliance with codes, standards and best practices, both existing and future.**

A set of recommended actions is developed below that supports this overall strategy. In our recommendations we also outline potential policies and incentives that help support implementation of mechanical insulation and best practices in construction—these may be created by local governments and by third parties such as energy utilities. However, from a strategic perspective, it is clear that a unified and compelling set of changes at the senior government level, stemming primarily from building codes, is preferred over a patchwork of local government policies (or a lack of uptake by local governments), to achieve a consistent, improved level of performance across BC.

2. Senior Government Action and Building Codes

- 1. Objective: Update the BC Building Code and Vancouver Building Bylaw to include specific, up-to-date requirements on mechanical insulation.**
- Include a clear, mandatory requirement for mechanical insulation in Part 3 buildings, referencing minimum insulation requirements tables as per the appropriate version of ASHRAE 90.1. E.g., ASHRAE 90.1-2004 for the existing BC code; to be updated as the building code reference newer versions of ASHRAE standards.
 - While the current code does reference ASHRAE 90.1, the mandate to install mechanical insulation is not sufficiently clear, as evidenced by varying interpretations in industry and local government.
 - Alternatively, an authoritative ruling or bulletin by provincial authorities could serve to clarify what is required by the code.
- Include references to mechanical insulation best practice standards, such as:
 - BC Insulation Contractors Association’s Quality Standards for Mechanical Insulation; and
 - Thermal Insulation Association of Canada’s Best Practice Guidebook.
- Include clear qualification requirements for mechanical insulation contractors and installers.
 - Existing requirements cover some safety aspects but do not cover all mechanical insulation aspects.
 - Existing programs include the Industry Training Authority/BC Trades Qualification or through the Interprovincial Standards Red Seal Program.
- Further distinctions around the applicable minimum building scale/type may be warranted.

Recommended Action:

Initiate discussions within BC Building Code and Vancouver Building Bylaw updating process to ensure future versions of the code/bylaw incorporate up to date mechanical insulation standards based on ASHRAE, and incorporate minimum qualifications for installers; ideally provisions are included in the new BC Building Code expected in late 2011.

2. Objective: Update the National Building Code and Model National Energy Code for Buildings with up to date requirements on mechanical insulation.

- The Thermal Insulation Association of Canada and other industry representatives and consultants have been providing recommendations to the NRC Canadian Codes Centre concerning updates to future versions of the National Energy Code for Buildings.

Recommended Action:

Continue to liaise with Thermal Insulation Association of Canada (TIAC), the BC Insulation Contractors Association (BCICA) and other stakeholders toward a strategy for ensuring future versions of the NECB incorporate up to date mechanical insulation standards, ideally including the NECB expected in late 2011.

3. Require that building officials (or third party independent inspectors) are tasked with mechanical system inspections.

- Given the potential impact of mechanical insulation deficiencies, the province should require mandatory local government site inspections, including mechanical systems and mechanical insulation, to augment the field reviews conducted by the registered professional.
- This action is in-line with the recommendation of the BC Climate Action Team made in their 2008 report: Meeting British Columbia's Targets.⁴⁸
- Many local governments currently do not conduct site visits for Part 3 buildings, due to limited human and financial resources and liability concerns as discussed earlier in the document.
- Increased inspection of mechanical insulation may be most practical with an update to the building code that clearly defines minimum insulation requirements; inspectors may be better positioned to verify that minimum requirements have been met (e.g. pipes that should be insulated are insulated) and that there are no obvious deficiencies.
- Increased inspection of mechanical insulation would need to be supported with educational programs for inspectors in order to be effective.

Recommended Action:

Identify local government champions for this issue and allies within the Building Safety and Standards branch and the Energy Efficiency Branch of the BC Provincial government. Change the appropriate sections of the Community Charter and BC Building Code during the 2011 building code update process.

⁴⁸ http://www.env.gov.bc.ca/cas/mitigation/pdfs/CAT_FINAL_REPORT_July_23_2008.pdf

3. Local Government Policies and Programs

There are a number of ways that local governments can encourage and facilitate mechanical insulation best practices, with or without the benefit of progressive changes to building codes. For most local governments in BC, due to lack of authority over building codes, other types of policies and programs are more appropriate. However, as discussed earlier in this section, development of policies specific to local governments can potentially result in a patchwork of different requirements across BC for developers and industry to deal with, contributing to higher development costs and uncertainty in the market, and resulting in a limited penetration rate.

However other important roles for local government include helping to support and facilitate change at the provincial level, and facilitating change at the local level through education and standards enforcement.

Examples of local government policies and programs include the following:

1. Create or update Development Permit Checklists – Planning Departments

A number of local governments already require developers to complete sustainability checklists as part of development permit processes. Generally these checklists are mandatory to complete, but the local government does not (and cannot) require a minimum criteria with regard to energy performance or completion of checklist items that overlap with the building code scope. Options include:

- Incorporation of mechanical insulation checklist items within broader sustainability checklists. These broader checklists could be augmented with one or more additional checklist items that would help raise awareness of insulation best practices.
 - E.g.: The project design and construction team will apply a recognized, current standard for mechanical insulation (insulation of pipes, ducts and equipment).
 - Include a reference to recognized standards and resources

Recommended Action:

Consider incorporating a mechanical insulation checklist component within development permit checklists and/or sustainability checklists. This list should include reference to best practice standards that are contained within the *BCICA Quality Standards for Mechanical Insulation* or the *TIAC Best Practices Guide*.

2. Create or update Building Permit Checklists – Building Approvals Departments

Require the incorporation of a mechanical insulation checklist as an element of a Building Permit application for Part 3 buildings – i.e. commercial, institutional and industrial buildings, optionally of a minimum size. This checklist item could also be part of a sustainability checklist (if one exists) for building permit applications. As explained above, compliance with checklist items would generally be voluntary, though completion of the checklist could be made mandatory through the building bylaw. Examples of checklist items include:

- The project mechanical engineer/registered professional is implementing mechanical insulation best practices through application of a recognized, current standard for mechanical insulation in design, such as ASHRAE 90.1 (2004 or later) or ASHRAE 189.1, and has developed a plan for inspection.
- The project contractor(s) responsible for mechanical insulation procurement and installation is/are qualified under a recognized mechanical insulation certification program (see examples under the first set of recommendations).

Recommended Action:

Explore the creation or updating of a building permit checklist as outlined above, as appropriate to fit within or augment existing development and building approvals processes.

3. *Municipal building construction and retrofits – Facilities and/or Purchasing Departments*

Local governments can take steps to minimize energy and cost performance impacts of mechanical insulation deficiencies in their own buildings, as well as gaining experience and showing leadership on energy efficient building practice.

- Incorporate policy and/or procurement guidelines that require mechanical insulation best practices to be included in construction and retrofit RFPs and tenders:
 - Include clauses similar to the Building Permit Checklist items listed above.
 - In addition, local governments can require compliance with ASHRAE 90.1-2010 insulation thickness tables.
 - Include provisions for mechanical insulation best practice specific to building retrofits:
 - E.g., for building energy assessments, inspect mechanical systems for deficiencies and assess opportunities for energy and financial performance improvements through mechanical insulation improvements.
 - Require inspection of mechanical insulation by city building code officials.

Recommended Action:

Explore and pursue the policy mechanisms described above to ensure that local government owned buildings are built and retrofitted to best practice mechanical insulation standards.

4. *Building Bylaw requirements for qualified mechanical insulation contractors – Planning/Engineering Departments*

Though requiring minimum energy performance or specific best practices is generally not within local government authority, a local government could⁴⁹ require developers to ensure that mechanical insulation contractors are qualified under a recognized mechanical insulation certification program as a part of rezoning negotiation (as mentioned in the Senior Government Action section earlier). However, this requirement is ideally implemented at a provincial level.

⁴⁹ A review of the legality of this authority is recommended.

In the absence of provincial code changes in this regard, local policy (pending legal review) could include:

- For commercial, institutional and industrial new development projects requiring a building permit, with a total conditioned floor space of 500 to 1000 square metres or greater:
 - The project contractor(s) responsible for mechanical insulation procurement and installation shall be qualified under a recognized mechanical insulation certification program:
 - Industry Training Authority/BC Trades Qualification or Interprovincial Standards Red Seal Program.
 - The project applicant must provide a completed and signed contractor declaration form prior to occupancy permit. There are existing examples of these types of forms – for example for envelope insulation.
 - The form would state the qualifications and provide a signoff by the contractor.
 - The form would be included in building permit information packages for applicants – e.g. at permit desk and municipal web site.

Experience from other industries, including the Roofing Contractors Association of British Columbia who were interviewed for this paper, suggests that previous efforts to incorporate minimum qualification requirements in building bylaws resulted in minimal uptake (see Appendix A).

Recommended Action:

Monitor progress toward provincial code provisions for minimum qualifications, and pursue local government bylaw changes for minimum qualifications if appropriate.

5. Build staff capacity to address mechanical insulation issues – Planning, Engineering and Building Approvals Departments

Local government education and training programs can support all the above actions. Refer to the Industry and Local Government Education and Capacity Building later for more information.

4. Utility Incentive Program

Financial incentive programs for building related technologies and practices are an effective policy tool to reduce energy use, decrease first cost barriers associated with new technologies and to raise awareness about the energy benefits of specific technologies and practices. Currently, there are not any financial incentives for mechanical insulation offered by the federal government nor the provincial government or utility companies in British Columbia. The creation of such a program would address several of the current barriers to good mechanical insulation practice that currently exist: lack of awareness of the importance of mechanical insulation to building energy performance and first cost orientation of building owners.

A number of jurisdictions in the United States currently offer loan programs and rebates for the purchase and installation of insulation for heating and cooling systems and associated piping and ductwork (see sidebar, below). An appropriate example for the BC context is California—a state that has set equally aggressive greenhouse gas emission reduction goals and has been a

North American leader in building energy efficiency. The California Public Utility Commission created an energy efficiency plan for 2010-2012 that includes a comprehensive list of products that are eligible for rebates for both the commercial and residential sectors. The individual utility companies administer the programs and issue the rebates, while the program goals, framework and some funding come from the State.

For the 2010-2012 period, businesses in California can receive the following rebates for MI related products:⁵⁰

Pipe Insulation

- 1" Pipe Insulation, Hot Water (120-200° F) - \$2.00/linear ft.
- 2" Pipe Insulation, Hot Water (120-200° F) - \$3.00/linear ft.
- 1" Pipe Insulation, Low Pressure (<15 psig) - Steam (200 - 250° F) \$3.00/linear ft.
- 2" Pipe Insulation, Low Pressure (<15 psig) - Steam (200 - 250° F) \$4.00/linear ft.

Tank Insulation

- 1" Tank Insulation, Low Temp. Solution (120-170° F) - \$2.00/square ft.
- 1" Tank Insulation, High Temp. Solution (170-200° F) - \$3.00/square ft.
- 2" Tank Insulation, Low Temp. Solution (120-170° F) - \$3.00/square ft.
- 2" Tank Insulation, High Temp. Solution (170-200° F) - \$4.00/square ft.

MI Rebate and Loan Incentive Programs

(examples)

PG&E, California – [Commercial](#) and [Residential](#) Rebates

Clallam County Public Utility District, WA – [Loan Program](#)

Tallahassee, FL – [Residential Loan Program](#)

Nebraska Energy Office – [Energy Savings Loans](#)

The New York State Energy Research and Development Authority – [Gas Efficiency Performance Based Incentive](#) and [Residential Energy Affordability Program](#)

Recommended Action:

BC Hydro, Terasen Gas and Fortis BC should put in place rebate programs for both commercial and residential customers that include mechanical insulation. The costs to the utility companies to provide an attractive rebate on insulation would be less than many of the other products that are currently included in financial incentive programs because of the low cost of insulation compared to the mechanical systems that they are associated with (1/10th of the cost, as general rule of thumb). Because of its role in setting provincial energy policy and targets, the B.C. Ministry of Energy could collaborate with the Building and Safety Standards Branch of the Ministry of Public Safety and Solicitor General to ensure that mechanical insulation is included among the technologies/practices that are targeted by building energy efficiency programs.

5. Industry and Local Government Education and Capacity Building

Building the capacity of industry to implement best practices is critical to achieving mechanical insulation objectives, and realizing the energy and emissions opportunities outlined earlier. Education and training of local government, primarily building inspectors, can also support

⁵⁰ Pacific Gas and Electric Company, Energy Efficiency Rebates for Your Business, 2010-2012 Product Offerings, http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/product_offerings.pdf

enforcement of code provisions and best practices. As one example, the BCICA Quality Assurance certificate program is currently in development.

Elements of education and training programs should address issues including:

- Creating awareness of the importance, impacts and issues associated with mechanical insulation
- Mechanical insulation design and inspection practices in engineering
- Contractor training in insulation best practices
- Standards and specifications
- Addressing mechanical insulation in building retrofits, as well as new construction

Recommended Actions:

- Work with industry and professional associations to advance education and training opportunities and market penetration, including promotion of existing initiatives like the BCICA QA program. Potential partner organizations include:
 - Association of Professional Engineers of BC;
 - Applied Science Technologists and Technicians of BC;
 - Architectural Institute of BC;
 - BC Institute of Technology;
 - Building Officials Association of BC;
 - Building Owners and Managers Association (BOMA) of Canada;
 - Canada Green Building Council;
 - Cascadia Region Green Building Council;
 - Real estate foundations, strata management associations and companies (our understanding is that the Insulators Union has already initiated discussions with some of these).
- Work with local governments and associations (such as the Union of BC Municipalities) to develop and promote education and training opportunities for staff, particularly building inspectors. The scope of this education and training could parallel that for industry, but would likely have a focus on inspections.
- Write a technical bulletin on the mechanical insulation requirements in ASHRAE 90.1 and the BC Building Code and disseminate this to building inspectors, engineers and the Building Policy Advisory Committee within the Ministry of Public Safety and Solicitor General.
- Work with TIAC and BCICA to include a sustainability section in their standards/guidelines, informed by the findings in this report.
- Develop a third party inspection qualification program to support local governments in the absence of a clear mandate for local government building inspections, and work with educational institutions (e.g. BCIT) to deliver the education programs.

6. Future Research Directions

This report examines at a high level the current state of practice and the opportunity that exists for saving energy and reducing GHG emissions from improved mechanical insulation installation and standards. The recommendations put forward have been tailored to address the challenges that were identified through the industry interviews and opportunities that were revealed through the literature review and building energy modeling. Several of the recommendations would benefit from or require additional research and modeling. This includes:

- Modeling and energy audits to identify energy savings potential and best practices for low temperature heating systems;
- Conducting energy audits of a representative sample of existing multi-unit residential, commercial and institutional buildings to assess energy and emissions reduction opportunities, and to assess the cost effectiveness of mechanical insulation retrofits on different building and system types.

Appendix A – RCABC Guarantee Corp

Roofing Contractors Association of British Columbia – RCABC Guarantee Corp

The RCABC Guarantee Corp. (RGC) operates a Guarantee Program, providing a third party guarantee service for Industrial, Commercial and Institutional Roofs, which is a first in Canada. The program works as follows⁵¹:

- The RCABC maintains roofing standards, which are regularly reviewed and updated;
- Owners/architects will specify that a project be built to the standards, and covered under the guarantee program;
- Contractors register with the program;
- Independent inspection firms, certified by the RGC, conduct random audits of registered projects; and
- The RGC guarantees the work, for five or ten years.

Information received from an interview with the RCABC Guarantee Corp:

- The RGC Guarantee Program's success has been driven by the private sector. Designers appreciate having expert 3rd party inspections to support their field review, and assume liability.
- The RGC Guarantee Program is market driven; architects like having additional oversight to ensure good roofing practice and liability for failure diverted to the RGC. The architects and consulting community have been the supporters – would focus on these interest groups in the context of the BCICA's QAC program.
- The RCABC, in collaboration with WorkSafe BC, has approached local governments in the past requesting that building bylaws dictate that roofers be licensed by the RCABC. This was because of safety concerns; roofer falls are a major source of claims for WorkSafe BC, and RCABC licensed roofers are trained in safety best practices. However, no local governments adopted this language, and the pursuing this policy was dropped. The current provincial government has focused on relaxing builder regulations, licensing, and inspections.

⁵¹ RCABC. 2009. RGC Guarantee Program. Accessed July 16, 2010 <http://www.rcabc.org/rgc-guarantee-program.php>

Appendix B – Industry Interview Results

1. Findings/Responses

The responses from the interviews have been organised into subsections corresponding with each group that was interviewed.

1. *Building Officials and Inspection Professionals*

i. Oversight of mechanical insulation practices by Local government building departments is very limited.

- Some Local Governments (“LGs”) do not review Part 3 buildings onsite at all.
- Other LGs visit construction sites to review whether Registered Professionals’ Letters of Assurance are substantially accurate; however these visits do not constitute detailed inspections. Few LGs perform detailed inspections.
- Site visits are generally focused on fire safety, structural issues, and other issues pertaining to immediate human safety. **Energy efficient construction is rarely reviewed.**
- Few LG building inspectors have a background in mechanical systems.
- LG Building Departments are generally not funded sufficiently to conduct more comprehensive inspections. LGs are motivated by liability concerns, which act to limit the depth of inspections that they perform.
- It is the general view among building inspectors that they do not have the authority to comment on the quality of workmanship, nor enforce quality standards reference in the building code or best practice guidelines.

ii. Frequent non-compliance with the BC Building Code

- Estimates vary within local governments of the rate of non-compliance with aspects of the code, and most first hand evidence is drawn from a limited number of site visits. However, building officials cite frequent code violations of some form or another.
- One building official from a local government that conducts relatively comprehensive inspections cited a case where mechanical insulation was noted to be poor and non-code compliant:
 - Substantial lengths of pipe required to be insulated were exposed;
 - Fire stopping issues;
 - Insufficient flame spread rating and smoke development rating in mechanical insulation products;
 - Insufficient dimensions of mechanical insulation; and
 - Improper application of piping clamps.

iii. Reasons for poor practice

- Lack of training amongst many trades.
- Lack of qualified trades (especially during economic booms).

- Lowest bidder (engineering firms and contractors) typically wins (especially during economic lulls).
- Emphasis on rapid construction.
- Designers (registered professionals) sometime lack knowledge of code, are unfamiliar with material applications, and are unavailable to conduct inspections.
- Material availability. Contractors are accustomed with doing business with one supplier or local lumberyard. If the precise thickness or type of insulation that is specified is not available, they will use whatever is available.

iv. Suggestions for Improvements

- The Ministry of Housing and Construction Standards stated that they are committed to developing a building code that sets standards for construction; and that it would not be appropriate to specify who can perform the work. If a third party assurance program were to be established, it would need to be done independent from the provincial government.
- Devolving more inspection authority to local governments is not seen as an appropriate step because of their reluctance to take on the liability associated with this. Many small and medium sized local governments also do not have the capacity to perform building inspections.

v. Best Practices from other Industries

- The RCABC Guarantee Corp. (RGC) operates a guarantee program, providing a third party guarantee service for industrial, commercial and institutional roofs, a first in Canada.
- The Master Painters and Decorators Association of BC has established standards for quality paints, and certifies products to these standards. Program originated in BC, now used by groups all over North America in their specifications (including Department of Defense).

2. Mechanical Insulation Contractors

i. Extent of Good Practice in Mechanical Insulation

- Poor amongst those who have not been trained in it.
- Larger firms tend to have best practices.
- Several contractors felt that poor practice is a regular occurrence.

ii. Reasons for poor practice

- Engineering specifications are outdated and do not cite best practices and products available.
- Other contractors believe that 95% of the specifications for mechanical insulation are correct. The problems occur when the insulation is installed.
- Some contractors correct specifications if they notice a problem with them. This is usually handled with an addendum.
- The inspector's attention is not on the mechanical systems—it is elsewhere.
- The engineers that inspect the work do not know what constitutes best practice. If they do, they are rarely able to tell when an installation has occurred that does not meet the specifications.

- Tendering processes overwhelmingly select the lowest bidder, and sometimes the budget is not sufficient for good work to be performed. “Value engineering” is a regular problem, where engineers are asked by developers to reduce the costs associated with installations.
- Contractors will sometimes intentionally reduce insulation thicknesses and sacrifice careful installation techniques because they know they can get away with this and it saves them money.
- Much of the mechanical insulation in the Lower Mainland is performed by non-unionized shops, or other trades (plumbing, mechanical contractors). These firms rely less on proper training and employees have not been through apprenticeship programs. For example, the majority of the pipe insulation in Vancouver is performed by plumbers; typically only hot water piping will be insulated; this creates condensation concerns on other types of piping.
- Buildings where the developer is not the eventual owner or operator have the poorest practices. There are cost incentives to cut corners during construction, with little concern about operating costs or maintenance. High-rise residential standards and large retail commercial are especially poor.
- Contractors feel a lack of empowerment or obligation to fix problems.
- For commercial and residential buildings neither the developer nor the engineers involved in the job view mechanical insulation as integral to a core function of the building, in contrast to the situation with mechanical insulation for most industrial applications. As a result, there is not the same attention to detail for commercial and residential installation as there is with industrial systems.

iii. Opportunities to Improve Practice

- Training more contractors that install mechanical insulation through the BCICA-BCIT program.
- Expand efforts to educate engineering firms on best practices and what to look for when conducting inspections.
- Institute a better inspection system. BCICA is in the processes of designing a quality assurance program. For developers that choose to participate in the program, the inspection would be performed by an independent third party, as opposed to the engineer. There would be a cost associated with service, but with successful education and marketing, developers could come to recognise the value it provides. This program would take the inspection trying to push through a quality assurance program. This would take the inspection out of the hands of the engineer. Money is the bottom line. The engineer could request it to be a qualified program and there would be a fee associated with that.
- The Province could build capacity among local building officials and expand their authority and the scope of the inspections they perform to include elements beyond just fire stopping.

3. Mechanical Engineers

i. Extent of good practice in mechanical insulation

- Generally only see mechanical rooms; do not see inside walls, so cannot comment on quality of much pipe & duct insulation.

- Despite specifications, often times mechanical insulation is missing. For instance, valves and pump housing are never insulated.
- New construction tends to have better insulation. Existing building's insulation is frequently taken off to repair leaks.

ii. Mechanical insulation's impact on building energy efficiency

- Mechanical insulation does not have a large impact in building energy performance. Potentially 1% of annual energy costs. Heat lost in wall cavities, mechanical room can still provide useful heat in building.
- Energy problems are solved most effectively using building automation, mechanical system controls, and operator training.

iii. Reasons for poor practice

- Mechanical room equipment is typically among the last building components to be installed. Often inspections don't cover complete mechanical rooms.

4. Mechanical Insulation Suppliers and Manufacturers

i. Extent of Good Practice in Mechanical Insulation

- It is known who the "hack" contractors are. Through peer pressure, their feet are sometimes put to the fire.
- Union vs. non-union membership is a big factor.
- The west coast of BC is where practices are the worse among the markets in BC, AB, Saskatchewan, Manitoba and the Yukon.

ii. Reasons for poor practice

- The installation and inspection system currently lacks checks and balances. The incentives to cut corners out-weigh the costs from the perspective of the installers and the mechanical engineers.
- In a two year mechanical engineer degree program, four or five hours are spent on mechanical insulation.
 - Sometimes products are specified that have not been available for more than a decade.
- There is bragging among contractors as to who can get away with the most regarding cutting corners and doing work that is not performed to specifications.
- An increasing number of insulation supply companies have entered the marketplace both domestically and overseas. Some of these newer suppliers sell products that are less expensive, but also lower quality.
- It is very easy for new insulation suppliers to enter the marketplace.
- You can get a good mechanical insulation contractor put on a poor quality product and it will look fine. The training of people in the industry plays a big role.
- Engineers and installers do not typically work closely together on jobs. This used to be more common.
- On the commercial side there is no peer pressure to stop poor practice. There are almost bragging rights for fleecing clients.

- There are more non-union mechanical insulation contractors doing work in the commercial building sector.
- Dry-wall contractors have the most power on site among the trades. For high-rise buildings, the scheduling is often so tight that the time between the plumbing and dry-walling is a day or two. The insulator does not have time to the job properly. It is not uncommon for the drywall to be installed on the weekend, at a time when the engineer is not working and has not had an opportunity to inspect the mechanical insulation.
- Plumbers are currently doing a lot of their own insulation.
 - Insulators used to be a part of the plumbers union; then the two groups separated. Since then the knowledge of good insulation practice among plumbers has gradually decreased. And in order to save costs, developers employ the plumbers to do their own insulation.
 - This practice has led to degeneration in standards through the following process.
 - On a typical job the mechanical contractor hires the plumber, and the plumber in turn hires the insulator. The mechanical contractors see the poor quality work that the plumbers do when installing the insulation so decide that they can use their apprentice instead of the plumber, because they can do the same quality of work and cost one-fourth as much. The low quality work of plumbers and some insulator contractors is driving this trend.
- For more advanced, low-temperature mechanical systems the specification or mechanical insulation are usually too vague.
- Most engineers and mechanical insulation contractors do not understand the importance of insulation choice for low temperature heating and cooling systems. Because of the higher costs and less common availability, engineers and contractors frequently substitute products that are inappropriate for the job.

iii. Opportunities to Improve Practice

- BC Hydro, the federal government or the province could offer financial incentive programs for the installation of mechanical insulation. These types of incentives are commonly offered by utility companies in the US.
- The BC Building Code could be updated to include master specifications for different building types and mechanical systems. These standards would then need to be enforced through inspection.

2. Conclusions drawn from the Interviews

Solutions for reducing the occurrence of poor practice

- ***Educate Engineers and Developers on the Importance of Good Mechanical Insulation*** – Use the results from building energy modeling conducted as a part of this report, with the possible combination of additional studies to prepare simple guidelines targeted at engineers and developers that discuss the energy, fire safety and mechanical system longevity implications of good and poor insulation practices.

- ***Educate Developers About the Value of Good Mechanical Insulation Practice for the Future Owners of their Buildings*** – Just as the development community is beginning to recognise the value of green building and energy efficient building practices in their multi-family housing projects—as a result of market demand and an increasingly educated pool of potential home buyers—this recognition could expand to avoided maintenance costs and improved energy performance as a result of certified good insulation practice. In the Lower Mainland of BC where the general public has seen periodic news stories that highlight the expensive effects of poor building practices—such as leaky condos—a potential buyer is likely to see the value in a system that brings a level of assurance to construction standards.
- ***Research and Education on Mechanical Insulation Best Practices for Low Temperature Systems*** – A small number of insulation contractors and suppliers in BC have experience with low temperature heating and cooling mechanical systems. The knowledge of these contractors and suppliers should be captured in order to create a best practices guide that can be distributed among mechanical engineers, insulation contractors and developers.
- ***Third Party Inspection System to Verify Good Practice*** – Engineers and contractors mentioned the need for an independent verification system and body to inspect mechanical insulation work. The creation of such a system, while far from simple, could be implemented with fewer obstacles than expanding the scope of work of building inspectors to include mechanical insulation. Two keys to successfully implementing a third party inspection system that were identified by interviewees were 1) a training and certification program for the verifiers that ensures proper qualifications for performing the inspections, and 2) promotion and endorsement of the program by industry associations, the provincial government and local governments in order to create sufficient market demand for the verification service.

Appendix C – Description of BCICA Quality Assurance Certificate Program (Draft)

The following is a summary of the proposed Quality Assurance Certificate Program that was provided by the BCICA:

- The BCICA Installation Standards Manual has consistently provided best practices and guidelines for its members for over 50 years. The proposed Quality Assurance Certificate (QAC) Program is an additional tool that will help ensure good mechanical insulation practice. The QAC Program will provide a means of ensuring that the most energy efficient levels of insulation in a project are both specified and properly installed using assured quality and certified/tested materials and standards - all as certified by fully trained and qualified independent inspectors. The corresponding energy savings and reduction in associated GHGs will be substantial. This program is similar in concept and design to the Roofing Contractors Association of BC's "Guarantee Program" which has been successfully operating on a self-funded basis for several decades and has become industry standard in the commercial roofing sector.
- The increasing trend in the construction industry of minimization or complete elimination of insulation as a cost savings measure has raised concerns within the Association. There is also a concern over the use of non-certified materials and the use of poor installation practices with a focus on optimizing profits instead of quality and customer satisfaction. This has given rise to the proposal to implement the QAC program described herein as a means of ensuring that the most energy efficient and appropriate levels of insulation are both specified and properly installed using assured quality as well as certified and tested materials and standards. This will be certified on a per project basis by fully trained and qualified independent inspectors.
- This program will involve wide reaching coordination between industry, educational institutions and government.

Q.A.C. Draft PROGRAM OPERATION

1. Specifications of the Program will likely include:
 - a. details of performance requirements for materials approved under the Association's Quality Standards Manual ("Q.S.M."); or
 - b. a general statement that the works included in the job be performed to "Q.A.C./Q.S.M. Standards"; or
 - c. identification of a particular product approved under the Q.S.M. for use on the job.

- d. The Q.A.C. may only be provided through a member of the Association.
2. The project will then go to tender and the contract will be awarded with the Q.A.C. as a requirement.
3. The successful bidder applies to B.C.LC.A. or an affiliate (the "Issuer") for a Q.A.C. assignment number.
4. The Issuer accepts the application and assigns Q.A.C. pre-qualified inspector to the job as a certified insulation inspector ("C.II").
5. The inspections on a project are done at a minimum number and frequency as per the Q.S.M. standards or greater as may have been specified. Q.S.M. standards would be developed for number and frequency of inspections as part of the detailed Q.A.C. program design and would be based, among other things, on quantity of materials used, value of contract, complexity rating or other like criteria developed by the Q.A.C. Program Technical Committee (the "Technical Committee").
6. The cost of the inspection process (fixed fee) is built into the bid price. The fee is paid to the Issuer upon assignment of a QAC number and is allocated by the Issuer;
 - a. to the Issuer for Q.A.C. Program administration;
 - b. to the C.II for inspection services when done;
7. At the point that the job is started, the contractor would notify both the Issuer and the C.I.I. and the schedule and scope of inspections would be confirmed.
8. If the contractor requests or requires any variance from original specifications (e.g. product substitution) it must be pre-approved by the Issuer so that the Q.A.C. will be provided in the ordinary course. Approval of variances by the Issuer would be based on the Q.S.M. and/or consultation with the specifying authority.
9. After any job inspection by the C.I.I. a copy of a formal inspection report will be filed with the Issuer and the contractor. It will include provisional certification by the C.I.I. that the job to date has been performed to permit the Q.A.C. to issue in the ordinary course or alternatively will note specific deficiencies.
10. Remedy of listed deficiencies would ordinarily be required by the next scheduled inspection and report from the C.I.I. Upon the job achieving substantial completion:
 - a. a final inspection is performed by the C.I.I. and a certification is given to the Issuer that the job has been performed to allow issuance of the Q.A.C.;
 - b. alternatively, deficiencies are listed and no Q.A.C. will be issued until a clean final inspection is achieved;
 - c. the contractor has the responsibility to remedy all deficiencies.

11. The B.C.LC.A. Constitution, Bylaws and Policies will have requirements and recourse built in so that the Association may recover its costs of remedying any deficiencies if a contractor fails or refuses to deal with them thus allowing the Q.A.C. to issue. This is where the Q.A.C. is underwritten by the Association which adds its credibility to the Q.A.C. Program.
12. The Issuer will also provide through its staff mediation and quick settlement assistance for any disputes between a contractor and a C.I.I. and a contractor and any other party relating to performance under the Q.A.C. Program.

A critical aspect of this program is the training and mobilization of independent, well-trained and certified inspectors. This will be done in conjunction with BCIT and the Applied Science Technologists & Technicians of British Columbia.

Appendix D - Additional Photographs of Insulation Deficiencies

Source: International Association of Heat and Frost Insulators and Allied Workers – Local 118



Incomplete domestic water pipe insulation in unfinished condominiums in Vancouver.



Corrosion and condensation in new LEED platinum condominiums in Vancouver.



Corrosion and condensation in new Vancouver condominiums.



Sweating pipes in a medical building in Vancouver. Note insufficient space adds to the problem.



Further evidence of sweating and corrosion at a medical facility. Note that even though the insulation appears to be sealed along the longitudinal seam, the poor quality insulation vapour barrier is not performing as it is supposed to.



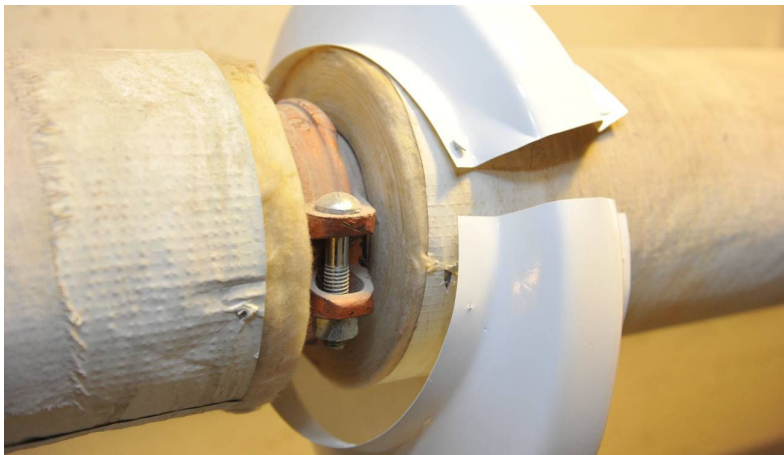
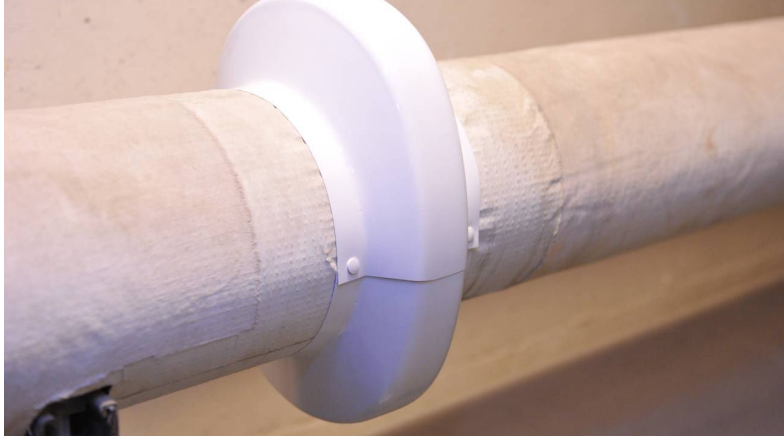
Incomplete and damaged insulation in underground parking of a retailer.



Poorly finished pipe covering in an outdoor parkade. No weather proof jacketing or elbows.



An example of an improper system with no vapour barrier and use of pink insulation instead of a matched density flexible insulation equivalent to the adjacent pipe covering.



The top photo suggests the pipe is fully insulated, but peel back the PVC cover and there is no insulation around the fitting. Private contractor insulation at a public service organization building in Vancouver.