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INTRODUCTION

Sustainable Buildings Canada (SBC) has recently undertaken to develop a program platform for the eventual implementation of the “Energiesprong” program in Canada. Energiesprong is a unique program approach to retrofitting buildings that was originally developed in the Netherlands. The program aggregates retrofit opportunities to present equipment suppliers and constructors with a large enough demand that encourages them to consider large-scale investment in providing the technical solutions. To date, the Dutch program has focused primarily on providing solutions for the social housing sector. SBC proposes to similarly focus on the social housing sector where aggregation of multiple projects can be achieved by engaging a small number of strategic housing provider partners.

The typical retrofit includes a major re-cladding of the existing home, a complete switch-out of the mechanical system, and the addition of solar photovoltaics. The intent is to industrialize the process through the use of pre-fabrication and off-site assembly which facilitates rapid deployment with minimal disruption to tenants. In the Netherlands, the entire retrofit activity typically takes two to five days.

The Energiesprong initiative is now being deployed in other countries in Europe and recently New York State has adopted the program for roll-out there. SBC is keen to fast-track the initiative here in Canada and has implemented a number of concurrent activities as a way to accomplish that objective. These include:

- Engagement with key housing providers and related associations in the province of Ontario;
- Review and assessment of housing provider assets resulting in the identification of priority projects for pilot implementation;
- Development of a detailed scanning process for select projects and scan to Building Information Modelling (BIM) model development;
- Development of a user friendly savings and cost estimating spreadsheet-based tool that provides a detailed net present value assessment;
- Energy modelling for the various options using townhomes in Toronto and Ottawa as the example projects;
- Design workshops in Toronto and Ottawa featuring subject matter experts focusing on key technical and policy issues.

This Phase 1 Report presents the results of the first workshop held in Toronto, the results of the scanning and scan to BIM model development, the review of the housing provider projects including the potential pilot project sites and the energy modelling results. Research and related activities regarding cost estimates and spreadsheet tool development are ongoing. The Phase 2 report will include the results of the Ottawa workshop, the energy modelling results for an Ottawa project, and the costs estimates for the various options. This report will be completed by August, 2017.
In co-operation with Energiesprong International and the Dutch Consulate, and with program content assistance from Natural Resources Canada, SBC hosted a one day workshop to review the Energiesprong zero energy approach to retrofitting social housing in Europe, and to investigate the feasibility of delivering such a program in Canada. The overarching goal was to identify solutions that will achieve the net zero energy target (or close to it) in a townhome project through the application of advanced envelope and mechanical solutions.

The workshop was facilitated by Mike Williams of RWDI with support from SBC Board members Bob Bach, Michelle Xuereb, and Taki Eliadis.

Over 60 participants from government, municipal housing providers, building science professionals, architects, and engineers participated in breakout groups examining both technical and policy issues and opportunities, and weighed those against the qualification criteria of the Energiesprong program. The criteria included:

1. Deliver a zero energy fuel cost solution.
2. Complete the onsite refurbishment within seven to ten days to minimize tenant disruption.
3. Pay for the refurbishment through avoided energy fuel cost and Operations and Maintenance (O&M) expenses.
4. Provide a comfort and performance guarantee for 30 years.

Participant teams focused their discussions in two distinct areas:

1. Technical solutions for envelope and mechanical components;
2. Policy issues and related recommendations.

Based on the experience in the Netherlands, the technical solutions envisioned generally fall into two major construction categories and three major mechanical solutions.

The two systems that will lend themselves to mass pre-fabrication construction techniques are stick frame and structural insulated panel (SIPs). These solutions will be applied over two existing scenarios for the exterior of the townhomes:

1. Brick
2. Siding

And under three existing space heating conditions:

1. Electric Baseboard
2. Forced air natural gas
3. Natural gas hydronic
Participants were asked to identify solutions, issues, and potential recommendations/outcomes that can address these various on-site conditions. Where solutions may differ depending upon the conditions, there should be an assessment of any distinct barriers or issues, including cost.

The Reference Project
The project examined was a four unit, two storey attached townhouse block owned by Toronto Community Housing Corporation and located in the Humber Acres Community in Etobicoke.

The construction is 1950’s vintage double brick construction with no interstitial insulation, plaster interior walls, double pane, single glazed windows, solid wood doors, a 2x6 framed gable roof with 4 inches of sealed batt insulation in the ceiling. The units are heated with a central atmospheric boiler and radiant baseboards, while domestic hot water is provided by rental, individually metered electric water heaters, and ventilation is provided by a principle exhaust fan located in the bathroom. Each unit is supplied with a 200 amp main distribution panel. An NRCan ERS audit was performed with units achieving air tightness tested at between 4.25 and 4.55 ACH at 50Pa.

Existing BuildingEnvelope

The business as usual case was represented by the Toronto Community Housing Reset program that has received $47 mil in Social Housing Apartment Retrofit Program (SHARP) funding to refurbish 900 units of apartments in three communities. Each project will include a field applied over cladding solution with the two preferred solutions being an Exterior Insulation and Finish System (EIFS) and a glass fibre reinforced concrete panel (GFCB).
Though both offered similar performance, the EIFS was thought to provide superior air barrier properties, although there are concerns with the durability. The Ontario Architects Association has issued a bulletin regarding Insurability for these assemblies. Although the GFCB is more durable, it comes at a cost premium; however, the installation can be completed in one visit.

Technical Discussion Highlights

Envelope – Wall Assemblies and Windows

The technical discussion was preceded by a short presentation from Natural Resources Canada (NRCan) on the Prefabricated Exterior Energy Retrofit (PEER) Project, which is currently developing prefabricated, panelized wall systems for retrofit in Canada. NRCan has developed details for two panel types: a conventional wood frame panel; and a structurally insulated panel (SIP). These are similar to systems currently employed by Energiesprong contractors in the Netherlands. Versions of these are evaluated by the SBC modelling team. For the purpose of this report, the following wall assemblies were modelled, as approximations. A third, vacuum-insulated system, inspired by the NRC / NRCan “Integration of Vacuum Insulation Panels into Canadian Buildings” presentation, is also included in this report.

**System 1 Wood Frame**

Exterior rainscreen  
1”XPS  
2x8 @ 24 O.C woodframe construction  
2 layers of R-14 rockwool batt  
Permeable membrane (house wrap)  
Flexible neoprene compression gasket
System 2 SIPS

Exterior rainscreen
7” XPS with 2 layers of 5/8” OSB
Flexible neoprene compression material

System 3 VIPS

Exterior rainscreen
OSB (7/16 in.)
2X3 wood frame @ 24 in. O.C. with rockwool batt
XPS (½ in.)
NEOPRENE
VIP (25/32 in.)
XPS (½ in.)
2X4 wood frame @ 24 in. O.C. with rockwool batt
Flexible neoprene compression material

There was considerable discussion amongst the groups around the need for air tightness, hygrothermal analysis, detailing of penetrations and preparation of existing masonry / substrates on the existing building. A structural analysis to determine the bearing capacity of existing brick that may be spalling was also recommended. It was noted that air tightness is a critical component determining energy performance as well as resilience so the need to ensure adequate attention to detailing is paramount. This will need to occur at both the panelization plant and as part of the actual installation.

The effectiveness of the wall assemblies and their adoptability by an offsite manufacturing facility will be critical. Current practices in the area are focused on wood frame construction with some automation of process while SIPS panel manufacturers are more automated. It was noted that there is a cost premium...
to vacuum insulated panels with no current facilities providing those in prefabricated assemblies other than in the refrigeration sector. NRCan has developed concepts for sandwich panels that incorporate VIPs. Long-term resilience testing is underway. Costs, durability, and moisture management, however, are still outstanding issues that need to be addressed before VIPs can be incorporated into prefab retrofit assemblies. Aerogel technologies were also discussed as an alternative to vacuum insulation for future consideration. Attendees concluded that the VIPs system may not be ready for cost effective broad scale roll-out in the near term, but may be an excellent solution in the longer term.

It was noted that the above-grade wall solutions did not take into consideration the basement walls and it was determined that an insulation skirt extending a minimum of three feet below grade would be an inexpensive solution with minimal tenant disruption. Protection of the insulation extending above grade needs consideration and vacuum panel insulation may be suitable for subgrade with appropriate protection.

There was a discussion around the effectiveness of installing SIPS roofing over the existing roof and the implications of changing above-ceiling attic space into conditioned space vs. increasing ceiling attic insulation. The need for modelling for additional volume in the attic space was discussed, and detailing the air barrier between the new wall panels and new roofing would need to be considered.

Fenestration

A detailed discussion of window options did not occur. Attendees were unanimous regarding the need for triple pane glazing systems. Selective glazing for orientation could be used to maximize solar heat gain and minimize overheating and cooling loads. U values with a maximum of 1.1 W/m² with selective heat gain through low e coatings (different coatings on different elevations) are recommended. As well, consider external shade devices and their potential application. It was also noted that detailing will again be critical. Whether they are pre-installed or installed on site, care must be taken to ensure they are properly sealed and integrated with the wall assembly. For systems that are pre-installed, adequate controls need to be in place to prevent degrading of seals during transportation.

Mechanical Systems

It was noted that the systems employed for space heating in Europe are almost exclusively hydronic whereas Ontario low rise social housing is mostly forced air gas or electric baseboard with some central hydronic. The Reference Building is central hydronic with baseboard radiant heating. As well, in the Netherlands, most of the retrofitted units have seen the installation of air source heat pumps.

Air conditioning is a recurrent problem with low SEER window A/C’s providing the bulk of suite air conditioning at considerable expense to housing providers and tenants where it is used. Adding air conditioning as a resiliency measure was recommended citing the City of Toronto Future Weather report as evidence of that need. As well, it was noted that window air conditioners would clearly compromise the air tightness of the windows and affect the overall energy performance. These should be avoided.

There was considerable discussion around primary fuel source as it was noted that the program is a “net zero energy fuel cost” so natural gas heating and hot water should remain an option as gas is relatively
inexpensive compared to electricity. Some attendees argued that the 30 year guarantee period would take the project beyond the 2030 carbon neutral goals of the City of Toronto and the Province. Options including next generation gas heat pumps, community scale combined heat and power units including micro CHP were presented as natural gas heat options while “green gas”, organic derived synthetic gases, cleaned and injected into the natural gas distribution present an emerging alternative to electrification.

Community scale geothermal was considered although construction costs would make paid-through savings unlikely. It was noted that that would change dramatically if the ground loop was assumed by the natural gas utility and included in their rate base capital expenditure. This could be a viable solution that might be explored for larger projects.

Air source VRV/VRF heat pumps including air to air mini splits and air to water hydronic systems in electric baseboard and hydronic applications would work well. Modulating, very high efficiency natural
gas furnaces coupled with air source heat pumps and control systems to optimize time of use rates were also discussed as potential alternatives. It was also noted that Passivehouse house level envelope performance, coupled with very high efficiency heat recovery ventilation could result in heating loads so low that natural gas based heating would not be required.

Ventilation in existing Social Housing is primarily passive via operable windows or a principle ventilation bathroom fan at best. Heat recovery (HRV) and enthalpy recovery (ERV) ventilators with efficiencies of approximately 80% are available although at a considerable premium to the more conventional 55% to 75% models, while air to air heat pump ventilators are beginning to make their way into the market. European heat pump ventilators are now a standard feature in demand side management and refurbishment programs in Europe although the air to water variety, returning recovered ventilation energy to the domestic hot water system are more common and could be considered in the Canadian context.

The hot water heater in the reference house was a rental electric 50 gallon storage water heater. Domestic hot water can be supplied by stand-alone single or split system heat pumps, integrated into either air to water or geothermal systems, and supplemented by drain water heat recovery and solar
thermal. It was noted however that the roof area available for solar thermal would have a better ROI as solar photovoltaic, especially if a feed in tariff (FIT) contract were made available for Social Housing.

It is anticipated that the air space located between the existing masonry or substrate, and any of the manufactured over cladding solutions could accommodate distribution systems like refrigerant lines, plastic plumbing hydronic distribution, or very small ducts for high velocity air distribution, as these will effectively be inside the building.
For the purpose of the workshop, discussion of renewable energy was limited to wind and solar, with issues around net metering and feed in tariff deferred to the policy group or subsequent discussions. Wind was determined to be ineffective in the application due to urban location, and tree canopy while it was noted that tree maintenance would be a requirement due to the maturity of trees on the site. The following picture provides an assessment of the potential solar installations on the site.

The reference home could accommodate approximately 4.5kwp of solar on the roof with additional capacity added as possible window shading/awning to also provide summer solar heat gain shading. The building is part of a larger community of TCHC housing that could accommodate a larger community energy system. Though the assessment focused on building-mounted PV, additional PV could be added as parking lot shading as well, adding additional capacity. Access to other roofs in the area for the purpose of contracted PV generation is another option that could be used as part of the net zero strategy.
Typical Retrofitted Roof Mounted System.

The PV system is mounted to the existing roof using exterior mounts and flashings to prevent moisture leaks. The existing roof is maintained with little or no change in thermal performance.
Energiesprong Installation

For the Energiesprong installation, the entire roof is covered with the panels and the panels are integrated with the roof system. The existing roof may be removed (dependent upon the specific in-situ conditions) or the new system may be installed on top of the existing roof. The new system includes insulation, bringing much greater thermal performance. New integrated systems can also pre-heat incoming air as part of the mechanical system.
POLICY GROUP HIGHLIGHTS

This session was facilitated by Taki Eliadis of Sustainable Buildings Canada and was attended by representatives from the various housing providers, municipal, provincial and federal government and utility representatives, and Energiesprong (ES) representatives from the Netherlands (NL).

This session focused on identifying key trends, issues, and barriers with respect to implementing a similar program here. Participants were asked not to focus on the cost of the installation as it is understood that these will be expensive; however, a successful implementation of the program will address the cost issue in a manner that does not impact the financial stability of the housing providers.

The following provides the highlights of the various discussions including recommendations.

- The group started with a discussion of the goals of the ES program in the Netherlands and the importance of understanding what the end goals are. In NL, one of the major goals was the complete removal of carbon as part of the energy supply. The program was designed with this as one of its strategic outcomes. As such, natural gas based solutions were not contemplated in the roll-out of the program. The group made the following comments:
  - The huge disparity between the price of natural gas and the price of electricity is an issue, with housing providers in particular indicating that ordinarily they would not favour electricity for space heating. Price signals tend to be more important that perceived energy efficiency opportunities.
  - Natural gas can be a bridge fuel. Attendees were concerned about removing natural gas altogether in the fuel mix.
  - Most providers are taking advantage of energy efficiency programs offered by utilities, however these are not deep retrofit programs such as what is contemplated with Energiesprong. Ideally, the ES initiative would integrate with utility programs.
  - Electricity infrastructure may not be able to accommodate a large migration of natural gas heating over to electricity. This would be the outcome if electric air source heat pumps are part of the solution.
  - In NL, the housing providers establish their contracted bill with the tenants and these act like a cell phone plan.
  - In Ontario, is it possible for a program like this to really drive policy?

Attendees also noted that any programs must understand the “asset management” considerations for their portfolios. Some parts of the portfolios are not good investments and any program schedules will need to integrate with planned investments and upgrades. The group made the following comments:

- There are densification issues within the portfolios with government expecting greater densities in certain areas. How would an ES style program play out in this environment? Again, it needs to be integrated with the investment plans. Part of the filtering process will require housing providers to participate fully in the selection of the projects.
- Envelope upgrades are a requirement for many providers already so it is a good opportunity.
• Mechanical systems may have been upgraded if they are natural gas. All electric (baseboards) have not been upgraded. Providers are very cognisant of the price of electricity and are generally not in favour of systems that rely on electricity for space heating.

• Interiors are also in dire need of repair in many cases. An ES style retrofit should also consider this need. Just doing the envelope and mechanical may not be enough.

The housing providers in the group identified a number of potential issues and barriers including:

• The Residential Tenancies Act (RTA) may act as a barrier to implementation; however, most non-profits are exempt from these conditions.

• Under the RTA, a landlord does not need a current tenant’s consent to install a suite meter. However, the tenant must consent before the landlord can instruct the suite meter provider to start billing the tenant directly for the electricity costs for the unit. It is up to the tenant to decide whether or not they want to start paying for their own electricity costs. They do not have to agree to the landlord’s request, but if they do agree, it must be in writing.

• The landlord must tell the tenant how much their rent will be reduced if the tenant agrees to start paying for their own electricity costs. This rent reduction is intended to offset the additional money that the tenant will have to pay to the suite meter provider once the tenant starts paying their own electricity costs. This information must be given to the tenant before the landlord gets the tenant’s consent. The landlord must inform the tenant of the amount that their rent will be reduced per rent period. The landlord must also show the tenant how the landlord calculated the amount of the rent reduction. The RTA has specific rules that a landlord must follow when calculating the amount of the rent reduction.

• Retrofitting sub-meters will likely be a challenge and will likely be heavily resisted by those who are currently bulk metered.

• Housing providers are required to follow specific purchasing and contracting guidelines that might limit their flexibility in an energy savings program. Government funding is typically established around specific timing and parameters unrelated to other programming activities.

• There could be lot line issues with the over-cladding for homes that are close together as the new wall assemblies could encroach on lot lines.

• There may be labour force barriers, challenges with unionized staff, or access to the properly trained trades.

• There may also be capacity issues with respect to pre-fabrication.

• Net metering regulations recently announced do not currently consider virtual net metering though it is being considered.

• The Province of Ontario currently limits the total amount of renewable energy allowed to supply to the grid for capacity and transmission considerations. A right to connect regulation should be established.

• Due to downloading of responsibilities to the Municipalities, some Social Housing Providers have gone to the private financing market to fund repairs. There may be existing loans or security interests that will take priority over any ES financing.
• Social Housing Providers may not have the staffing resources to evaluate their portfolio for eligibility. This needs to be considered as part of the program.

The NL experts provided a number of key insights which they believe are critical to achieving the goal of net zero, cost effective retrofits for the existing stock.

• The only way to achieve the cost effectiveness goal is through scale. There must be a large enough stock of potential to engage constructors and equipment providers and encourage them to change their business practices. In the initial stages, this will require government incentives to offset the cost. Over time, as the supply channels improve, the amount of government subsidy required will decrease.

• The program is a collaboration between the demand side (housing providers) and the supply side – constructors and equipment providers. The traditional spec and bid approach will not work. Rather, the two sets of interests must work together to develop the solutions. It is understood that costs will be high in the short term and mistakes will be made. This is part of the learning curve and must be allowed to occur without contractual constraints. Once this learning has occurred, the various performance contracts can be secured.

• The supply side must re-engineer both its technical practices and its business approaches. Ideally, the constructors will manage the supply side such that middlemen and related margins are eventually eliminated. To facilitate this, there must be enough demand (scale) to get the interest of the constructors and suppliers.

• The market is not just a local one. Initially, providers of equipment will likely be local; however, with the scale will come the interest of international equipment providers. Aggregating international ES programs means that the scale can be huge. This will have the potential advantage of further driving down the costs.

• The net zero outcome is the goal; however, for the tenant, the benefit is increased comfort and pride of ownership. The NL has experienced spillover benefits from the implementation of projects that include spruced up neighbourhoods and demand for participation in the program for adjacent communities.

• The tenant experience is critical. They must be part of the collaboration and the solutions. In the NL, significant effort goes into securing the tenants’ participation and buy-in. This includes focus groups, surveys, neighbourhood outreach efforts, etc.

• Housing providers have realized significant utility cost savings which have been reinvested in the portfolios. These savings can also be aggregated with state of good repair budgets to amplify the repair investments – in particular, it is used to undertake the interior retrofits.

• Performance contract includes specific maintenance requirements over the entire 30-year period. The housing providers are guaranteed high quality and performance.

• Eventually the need for the ES program diminishes as the housing providers contract directly with the marketplace for the deliverables under the performance contracts that are open source and made available to other providers.
REVIEW OF HOUSING PROVIDER HOUSING STOCK

Housing stock information was provided by 10 Housing Providers. Information included address, unit type, number of bedrooms, vintage and utility bill data (where available). SBC staff used the address data to assess each building and unit using a Google Map photograph identifying major structural issues, location of gas and electric meters and presence (or not) of chimneys and vents. On this basis, each project was rated on whether it would be considered a good candidate for the pilot project. Ideal candidates for the first pilot projects would have relatively simple exterior walls, easy access to the perimeter, and ideally be three to six side-by-side townhomes.

The following spreadsheet provides a sample of the analysis for Toronto Community Housing. As a result of the analysis, SBC has identified approximately 20 candidate projects for each housing provider. These represent the likely first pilot projects that will be delivered. Housing providers will ultimately decide on the appropriateness for each.

**Sample TCHC Projects.**
SCAN TO BIM ASSESSMENT OF THE THREE PROPOSED WALL SYSTEMS

Scan to BIM is a technology platform that takes point cloud scans of objects or topography and creates three-dimensional images which can then be manipulated within BIM software programs like Autocad or Revit. The process involves field scanning of the object using ground mounted laser scanners or aerial drones, which create point cloud files. These files are then manipulated to create images with tolerances as finite as 1mm that can then be layered with assemblies such as walls, windows, doors, and ceiling in exploded views to allow design integration of mechanical, electrical, and plumbing (MEP) in 3D. It allows design to accommodate actual site conditions like building settling or out of square assemblies when designing over-cladding to eliminate site adjustment. Field measurements of the Reference project were undertaken by the SBC team with the assistance of George Brown College. These measurements were rinsed through a BIM model to mock up the retrofit prototypes. These are presented in the following images.

Option 1: Wood Frame System
Option 2: SIPS System

Reference Roof
- Roof shingles
- Wood joists 2x6 with batt insulation

Double brick wall

Existing Wall

Roof System - SIPS
- SIPS - 10" EPS - 5/8 OSB
- Standing seam metal roof
- PV panels

SIPS
- GFCB exterior rainscreen
- SIPS - 8.5" EPS - 5/8 OSB

Existing Wall

Brick
Air gap
Brick
Drywall
Option 3: VIPS Superwall System

Existing

Reference Roof
- Roof shingles
- Wood joists 2x6 with batt insulation

Double brick wall
- Brick
- Air gap
- Brick
- Drywall

Options

Roof System - SIPs
- SIPs - 10" EPS - 5/8 OSB
- Standing seam metal roof
- PV panels

VIPS (Super wall)
- GFCB exterior rainscreen
- OSB sheathing
- XPS insulation
- VIP panel
- XPS insulation
- Wood frame structure - 2x4 @ 24 O.C
- Existing Wall
Window Options

Existing

Reference Roof
- Roof shingles
- 2x6 framed gable roof
- Batt insulation in the ceiling

Reference Window
- Single glazed vinyl windows

Reference Door
- Solid wooden doors

Options

Roof System - SIPS
- SIPS - 10" EPS - 5/8 OSB
- Standing seam metal roof
- PV panels

Window option
- Triple glazed Fiberglass frame

Door option
- Fiberglass door
ENERGY MODELLING RESULTS

Energy modelling using the Design Builder software was undertaken for the two wall assembly options – XPS and 2x8 with Rockwool, and the eight HVAC options. The energy model was developed using the drawings provided from the on-site measurements and the specification of the current HVAC system. This represented the “Reference Case” and is the point of comparison for all the various upgrade options.

HVAC Upgrade Options

Several technologies were considered for both domestic hot water heating as well as space conditioning. A mix of domestic hot water and space conditioning options were chosen, which are compatible with various possible existing delivery methods. These include:

Domestic Hot Water Options:

- Heat Pump Water Heating – outdoor source
- Heat Pump Water Heating – indoor source
- Natural Gas Water heater
- Gas Heat Pump (also used for space heating)
- Air-water heat pump

### Table 1: Space Heating and Cooling Options

<table>
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<th>Space Conditioning</th>
<th>Heating</th>
<th>Cooling</th>
<th>Distribution proposed</th>
<th>Existing Delivery compatibility</th>
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<td>mini/multi-split</td>
<td>DX fan-coil</td>
<td>Forced air/hydraulic/electric baseboard</td>
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<tr>
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<td>air-air HP</td>
<td>Ducted forced air</td>
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<td>Air-water HP~</td>
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<td>hydronic fan-coil*/forced air</td>
<td>electric baseboard/hydraulic rad/forced air</td>
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* Hydronic fan-coil proposed as delivery method instead of existing radiator to achieve latent cooling

Product links for each system are shown in Appendix C.

Likely combinations of these technologies were combined into 8 packages, each of which will provide space heating/cooling, as well as domestic hot water. Each package also includes the addition of mechanical ventilation with a heat recovery ventilator with a sensible heat recovery efficiency of 91%. The existing HVAC system of the building, with the addition of ventilation and heat recovery, is included as a point of comparison.

### Table 2: Modelled Retrofit HVAC Options

<table>
<thead>
<tr>
<th>#</th>
<th>Package Name</th>
<th>Space Conditioning</th>
<th>Delivery</th>
<th>DHW</th>
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<td>Radiators</td>
<td>Electric resistance</td>
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<td>1 S1</td>
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<td>DX fan-coil</td>
<td>HPWH-outdoor source**</td>
<td>91 SRE HRV</td>
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<td>mini/multi-split HP</td>
<td>DX fan-coil</td>
<td>HPWH-indoor source***</td>
<td>91 SRE HRV</td>
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<td>HPWH-outdoor source</td>
<td>91 SRE HRV</td>
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<td>forced air</td>
<td>HPWH-indoor source</td>
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<td>6 A3</td>
<td>air-air HP</td>
<td>forced air</td>
<td>Gas water heater</td>
<td>91 SRE HRV</td>
<td></td>
</tr>
<tr>
<td>7 W1</td>
<td>Air-water HP*</td>
<td>hydronic fan-coil</td>
<td>Air-water HP*</td>
<td>91 SRE HRV</td>
<td></td>
</tr>
<tr>
<td>8 G1</td>
<td>Gas HP + Window AC</td>
<td>hydronic fan-coil</td>
<td>Gas HP</td>
<td>91 SRE HRV</td>
<td></td>
</tr>
</tbody>
</table>

*An air-water heat pump is able to supply space heating/cooling as well as DHW.

**An air-water heat pump which is used to exclusively heat domestic hot water using the exterior air as a heat source.

***An air-water heat pump which is used to exclusively heat domestic hot water using the interior air as a heat source. The removal of interior heat increases heating loads, and reduces cooling loads.
Energy and Fuel Cost Analysis

Energy modelling was done using the Design Builder software, which uses Energy Plus as its calculation engine. Each of the HVAC packages were modelled with each of the envelope retrofit options. The end unit 2 was selected as the appropriate example, and its western attached wall is assumed to be adiabatic. Details for the energy model inputs are summarized at the end of the report in the "Model Inputs" section.

The efficiencies of the equipment used in the model are shown in the Table 3. In all cases, information was found on the various manufacturers’ websites.

### Table 3: Equipment Input Efficiencies

<table>
<thead>
<tr>
<th>Equipment Type</th>
<th>Fuel (G-gas, E-electricity)</th>
<th>COP/efficiency</th>
<th>Outdoor temperature at rated COP (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Space Heating</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas boiler</td>
<td>G</td>
<td>0.85</td>
<td>-</td>
</tr>
<tr>
<td>Mini-split HP</td>
<td>E</td>
<td>3</td>
<td>8.3</td>
</tr>
<tr>
<td>Air-air HP</td>
<td>E</td>
<td>4.6</td>
<td>8.3</td>
</tr>
<tr>
<td>Air-water HP</td>
<td>E</td>
<td>2.3</td>
<td>*</td>
</tr>
<tr>
<td>Gas HP</td>
<td>G</td>
<td>1.57 (^{1})</td>
<td>7</td>
</tr>
<tr>
<td><strong>Space Cooling</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mini-split HP</td>
<td>E</td>
<td>5.1</td>
<td>35</td>
</tr>
<tr>
<td>Air-air HP</td>
<td>E</td>
<td>4.4</td>
<td>35</td>
</tr>
<tr>
<td>Air-water HP</td>
<td>E</td>
<td>3.3</td>
<td>*</td>
</tr>
<tr>
<td>Generic AC</td>
<td>E</td>
<td>3.5</td>
<td>-</td>
</tr>
<tr>
<td><strong>Domestic Hot Water</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condensing boiler</td>
<td>G</td>
<td>0.95</td>
<td>-</td>
</tr>
<tr>
<td>Hot Water HP - indoor source</td>
<td>E</td>
<td>5.5</td>
<td>29 (^{2})</td>
</tr>
<tr>
<td>Hot Water HP - outdoor source</td>
<td>E</td>
<td>4.5</td>
<td>29</td>
</tr>
<tr>
<td>Air-water HP</td>
<td>E</td>
<td>2.4</td>
<td>*</td>
</tr>
<tr>
<td>Gas HP</td>
<td>G</td>
<td>1.57 (^{1})</td>
<td>7</td>
</tr>
</tbody>
</table>

* COP simulated in Toronto's climate using manufacturer data

\(^{1}\) Water delivery temperature of 50°C

\(^{2}\) Temperature of the indoor air
Energy analysis results are provided in Table 4 and figure 1. The values are in kWh and represent the consumption on an annual basis. Note that the results described as “Base” and “Reference in Columns 1 and 2 represent the annual energy load for the current HVAC and wall assembly. The results described as XPS and Reference are the XPS wall assembly and the current HVAC system. The remaining values are the various mechanical options.

### Table 4: Estimate Annual Energy Use (All values in ekW-h)

<table>
<thead>
<tr>
<th>Envelope</th>
<th>HVAC Option</th>
<th>Heating Consumption</th>
<th>Cooling Consumption</th>
<th>Major Appliances</th>
<th>MELs</th>
<th>Lighting Consumption</th>
<th>DHW Consumption</th>
<th>Ventilation Fans</th>
<th>Total Consumption</th>
</tr>
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<tbody>
<tr>
<td>Base</td>
<td>Reference</td>
<td>24108</td>
<td>0</td>
<td>2262</td>
<td>2240</td>
<td>2628</td>
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<tr>
<td>XPS</td>
<td>Reference</td>
<td>6665</td>
<td>121</td>
<td>2262</td>
<td>2240</td>
<td>2628</td>
<td>3516</td>
<td>302</td>
<td>17734</td>
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<tr>
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<td>1465</td>
<td>302</td>
<td>11448</td>
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<td>S3</td>
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<td>175</td>
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<td>2628</td>
<td>3701</td>
<td>351</td>
<td>13200</td>
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<td>A1</td>
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<td>175</td>
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<td>1591</td>
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<td>2628</td>
<td>1629</td>
<td>398</td>
<td>10534</td>
</tr>
<tr>
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<td>G1</td>
<td>1915</td>
<td>111</td>
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<td>1591</td>
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<td>2x8 w/ Rockwool</td>
<td>Reference</td>
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<td>130</td>
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<td>2240</td>
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<td>3516</td>
<td>346</td>
<td>18101</td>
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<tr>
<td>2x8 w/ Rockwool</td>
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<td>130</td>
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<td>2239</td>
<td>302</td>
<td>13624</td>
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<td>181</td>
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<td>2240</td>
<td>2628</td>
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<td>13235</td>
</tr>
<tr>
<td>2x8 w/ Rockwool</td>
<td>A1</td>
<td>1872</td>
<td>181</td>
<td>2262</td>
<td>2240</td>
<td>2628</td>
<td>1629</td>
<td>398</td>
<td>11210</td>
</tr>
<tr>
<td>2x8 w/ Rockwool</td>
<td>A2</td>
<td>2943</td>
<td>115</td>
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<td>2240</td>
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<td>1586</td>
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<td>181</td>
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<td>2240</td>
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<td>3701</td>
<td>351</td>
<td>12584</td>
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<tr>
<td>2x8 w/ Rockwool</td>
<td>W1</td>
<td>1221</td>
<td>181</td>
<td>2262</td>
<td>2240</td>
<td>2628</td>
<td>1629</td>
<td>398</td>
<td>10559</td>
</tr>
<tr>
<td>2x8 w/ Rockwool</td>
<td>G1</td>
<td>1919</td>
<td>115</td>
<td>2262</td>
<td>2240</td>
<td>2628</td>
<td>1586</td>
<td>400</td>
<td>11150</td>
</tr>
</tbody>
</table>

As shown, energy use for heating is the largest contributor to total annual energy, representing more than 60% of the annual load.
Figure 1: Annual Energy Consumption

![Annual Energy Consumption Graph](image-url)
Table 5: Percentage Improvements from Reference Case for each of the Retrofit Options

<table>
<thead>
<tr>
<th>Envelope and Proposed HVAC Package</th>
<th>Total % Improvement From Reference (includes other loads)</th>
<th>Conditioning and DHW % Improvement From Reference space heating load</th>
</tr>
</thead>
<tbody>
<tr>
<td>XPS, Existing HVAC</td>
<td>49.47</td>
<td>62.08</td>
</tr>
<tr>
<td>XPS, S1</td>
<td>61.85</td>
<td>77.62</td>
</tr>
<tr>
<td>XPS, S2</td>
<td>67.38</td>
<td>84.56</td>
</tr>
<tr>
<td>XPS, S3</td>
<td>62.39</td>
<td>78.30</td>
</tr>
<tr>
<td>XPS, A1</td>
<td>68.16</td>
<td>85.54</td>
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<tr>
<td>XPS, A2</td>
<td>65.33</td>
<td>81.99</td>
</tr>
<tr>
<td>XPS, A3</td>
<td>64.22</td>
<td>80.59</td>
</tr>
<tr>
<td>XPS, W1</td>
<td>69.99</td>
<td>87.83</td>
</tr>
<tr>
<td>XPS, G1</td>
<td>68.24</td>
<td>85.64</td>
</tr>
<tr>
<td>2x8 w/ Rockwool, Existing HVAC</td>
<td>48.43</td>
<td>60.77</td>
</tr>
<tr>
<td>2x8 w/ Rockwool, S1</td>
<td>61.18</td>
<td>76.78</td>
</tr>
<tr>
<td>2x8 w/ Rockwool, S2</td>
<td>66.92</td>
<td>83.98</td>
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<td>62.29</td>
<td>78.17</td>
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<td>68.06</td>
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<td>80.50</td>
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<td>2x8 w/ Rockwool, W1</td>
<td>69.92</td>
<td>87.74</td>
</tr>
<tr>
<td>2x8 w/ Rockwool, G1</td>
<td>68.23</td>
<td>85.63</td>
</tr>
</tbody>
</table>

As shown, the upgraded wall assembly yields very similar results for the two options – XPS and 2x8 Rockwool, providing approximately 50% reduction in total energy use. A further 10% to 20% improvement is possible through the application of the various HVAC options. Removing the base loads from the analysis demonstrates that up to 90% of the space and water heating load can be eliminated through the application of the recladding and the HVAC upgrade.
Energy Bill impacts
The energy use estimates have been converted to fuel costs, using current natural gas and electricity prices as provided by Enbridge Gas Distribution and Toronto Hydro. Note that in some cases, housing providers have contractual arrangements with energy providers where fuel costs have been established as part of a long term contract. The following analysis relies purely on published fuel costs as follows:

Natural Gas

- $20 Monthly charge, gas supply charge $0.114\$/m³, cap and trade $0.0335\$/m³, transportation to Enbridge $0.0543\$/m³, Delivery to you $0.0883\$/m³ (Assuming price for more than 170 m³/month).
- Total cost is $20/month fixed, +$0.29/m³

Electricity

- Assuming average time of use cost of $0.16/kWh
- Fixed monthly cost of $30.5*1.13 (HST) = $34.47

Regardless of which retrofit option is applied, the building will require electricity for the various appliances, plug loads, and lighting. For the purposes of the modelling activity, these are assumed to be constant pre and post retrofit and represent the “fixed cost” which is unaffected by the retrofit. The variable costs include the fuel costs for space heating/cooling, domestic hot water, and the monthly charge for gas connection since the retrofit may eliminate the need for natural gas altogether.
Due to the low cost of natural gas, the gas powered heat pump had the lowest ongoing fuel costs. The next best option was the air source heat pump for space conditioning combined with an exterior air source dedicated heat pump for domestic hot water. These two highly efficient options are able to supply all of the occupant needs with only electricity, eliminating entirely the natural gas load. This option also has the added benefit of having the greatest carbon reduction.

**PV Generation**

Using RETScreen, the potential electrical generation from PV was estimated. The assumptions used were:

- The entire $31m^2$ roof could be used, fitting 25 $1.24m^2$ panels.
- The nominal panel efficiency is 16.9%.
- Inverter efficiency is 90%, and there are an additional 4% miscellaneous losses.

The annual generation potential is estimated to be 6,300 kWh/year. At a rate of $0.17$/kWh, the annual revenue generated would be $1,071. While this is sufficient to cover the variable fuel costs for all of the retrofit cases, it is not enough to reach net zero annual energy costs when including the fixed costs. In fact, the fixed costs alone are greater than the potential revenue. If more efficient lighting and appliances were installed, it may help move the project closer to having net zero annual fuel costs. As it stands, additional off site PV or a higher "feed in tariff" rate will be required to achieve this.
**Basement Insulation Option**

At the design workshop, attendees noted that unlike the Dutch examples, many townhome units here have basements and these are often uninsulated. Further energy modelling identified that a large portion of the heating load is caused by the uninsulated basement walls and slab. Due to the basement being conditioned, it will lose heat to the ground even during the summer months, as the ground temperature is less than 21°C. As a result, a basement retrofit option may need to be added to the recladding package, depending upon the specific site conditions. For the purposes of this analysis it is proposed to add 2" of XPS insulation to the outside of the basement walls down to a depth of 1m from the surface.

This addition was tested using the 2x8 with Rockwool envelope option and reference building HVAC. Table 6 shows the annual heat balance for each floor. The heat loss due to surface conduction in the basement is by far the largest contributor to the space heating load. It and the required HVAC heat input are highlighted in Table 6.

<table>
<thead>
<tr>
<th>No Basement Insulation - Reference HVAC, 2x8 w/Rockwool Envelope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Floor</td>
</tr>
<tr>
<td>2nd Floor</td>
</tr>
<tr>
<td>Basement</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2&quot; XPS down to 1m from surface - Reference HVAC, 2x8 w/Rockwool Envelope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Floor</td>
</tr>
<tr>
<td>2nd Floor</td>
</tr>
<tr>
<td>Basement</td>
</tr>
</tbody>
</table>

The total heating energy consumption was reduced from 6979 kWh/year to 5821 kWh/year, a 16.6% reduction. This is significant decrease, and would also represent a significant impact on home comfort – particularly for homes that use the basements as living space.
Appendix A: Model Inputs

Geometry

- 3 floors
- Floor area/floor 50m$^2$ (6.68m x 7.5m), 538 sq. ft.
- 2 exterior doors, each 0.9m x 2m

<table>
<thead>
<tr>
<th></th>
<th>Wall Area (m$^2$)</th>
<th>Window Area (m$^2$)</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>42.88</td>
<td>7.35</td>
<td>0.146</td>
</tr>
<tr>
<td>East</td>
<td>60.11</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>North</td>
<td>59.45</td>
<td>3.4</td>
<td>0.054</td>
</tr>
</tbody>
</table>
Appendix B: Modelling Assumptions

These assumptions apply to the base model as well as the design iterations. Occupants are assumed to be gone during the day from 8am - 6pm, affecting internal body heat gains and electric lighting usage.

Domestic Hot Water Usage

- From Building America 2014 Simulation Protocols - 3 bedrooms, 211.3 L/day
- Even distribution between 1st and 2nd floor, at 2.11 l/m²/day

Occupancy

- Assume 3 occupants, 0.06 people/m² on top floors, 0.01 people/m² basement because it is less used

Appliances

- Washer/dryer in basement - 78 kWh/year washer (not including DHW), 1076 kWh/year dryer. 0.047 latent gain fraction, 0.194 sensible
- Range, Fridge, Dishwasher on first floor - 499, 434, 175 kWh/year respectively. 0.159 latent, 0.667 sensible heat gain fractions.
- Total large appliances - 2262 kWh/year
- Total miscellaneous electronics (MELs) - formula from Building America 2014 Simulation Protocols: 1185.4 + 180.2 X Nbr +0.3188 X FFA. Therefore total house is 2240 kWh/year. Evenly distributed for each floor. Sensible fraction 0.93, latent 0.02
- Usage schedules for each major appliance and MELs sourced from Building America 2014 Simulation Protocols

Lighting

- Lighting power density 4 W/m²/100Lux. second floor 150 Lux, basement 150 Lux, first floor 250 Lux

Construction - Base Model

Openings

- Doors - 0.9m x 2m, RSI 0.35
- Windows - RSI 0.23, SHGC 0.65, LT 0.83
- Shading - None

Basement walls

- 10cm concrete, plaster
- RSI 0.2
Above Grade Walls

- Brick 100mm, 50mm air gap, 100mm brick, plaster
- RSI 0.723

Flat Roof

- 2x6 studs, batt filled with 78% of R-value from bridging, Gypsum interior
- RSI 2.94

Air Tightness

- 4.73 ACH@50Pa

**Construction - For all upgrades options**

Roof

- 10" SIP added, OSB 1/2" on each side, RSI 8.5 added
- Sourced from: http://www.sips.org/technical-information/sip-r-values-calculated-r-values

Window Upgrade

- RSI 1, 0.38 SHGC

Doors Upgrade

- RSI 2.03

Air tightness

- Improved to 1.5 ACH@50Pa

**Construction - SIPS Option**

Above grade exterior walls

- Added continuous 7" of XPS at R-5/inch between two 5/8" OSB
- Final wall R-value 6.9
**Construction - 2x8 Frame Walls with Rockwool fill Option**

- Nominal R-28 added by Rockwool fill
- Reduced by 20% to account for thermal bridging through studs.
- R-22.4 effective added with Rockwool
- 1" XPS added continuously on outside
- Final wall RSI 5.58

**HVAC - Base Model (existing HVAC)**

**Space Heating**

- Boiler, 85% efficient
- Aux energy 252 W, or 1.68 W/m²
- HVAC fans - 344 kWh/year, based on HOT2000 model

**Space Cooling**

- Occupants assumed to have window AC units with a COP of 3.5

**Domestic Hot Water**

- 85% efficient, gas
- 55°C delivery temp, 10°C supply temp (avg)

**Mechanical Ventilation**

- None

**HVAC - Upgrade Cases**

**Mechanical Ventilation**

- Added ventilation as per ASHRAE 62.2. Exhaust requirements are: 20 CFM/bathroom + 5 ACH of kitchen volume. ASSUMING Kitchen volume is 1/3 of the first floor volume. Total = 20cfm x 2 + 5 x 1536 cf/hr x (1/60 min/hr) = 40 + 128 cfm = 168 cfm. Ventilation requirement is 150 cfm. 168 (60.4 l/s) will therefore be used to balance supply and exhaust. Applied equally across space.
- Result is 0.403 l/s/m²
### Appendix C: HVAC Upgrade Options Product Links

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-air HP</td>
<td><a href="http://www.daikinac.com/content/assets/DOC/SubmittalDataSheets/VRV/RXQ/460v/SDS-RXYQ96TYDN.pdf">http://www.daikinac.com/content/assets/DOC/SubmittalDataSheets/VRV/RXQ/460v/SDS-RXYQ96TYDN.pdf</a></td>
</tr>
<tr>
<td>Gas HP (for space heating and DHW)</td>
<td><a href="http://www.robur.com/heat_pumps/gas_absorption_heat_pump_for_homes_k18">http://www.robur.com/heat_pumps/gas_absorption_heat_pump_for_homes_k18</a></td>
</tr>
<tr>
<td>Generic Window AC</td>
<td>Any</td>
</tr>
<tr>
<td>Generic condensing gas boiler (DHW)</td>
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<td><a href="https://www.daikin.com/products/ac/lineup/heat_pump/">https://www.daikin.com/products/ac/lineup/heat_pump/</a></td>
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