ECONOMIC OPTIMIZATION OF THE BUILDING ENVELOPE FOR A HIGH PERFORMANCE MULTI-FAMILY RESIDENTIAL BUILDING

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Background

M.Eng. project initiated by a builder to answer questions:

- How to spent insulation budget efficiently?
- What point to stop spending money on the envelope?

Builder's original goal was net-zero

- Research goal was to find economically optimal configuration including levels of insulation and solar
- Original research plan plan was to use an optimization algorithm to reduce number of simulations.
- But net-zero found to be unrealistic for their 3 storey apartment building

Modified research plan:

- Gather data for all Combinations of envelope options to compare trade-offs.
- Had to reduce number of envelope options

Case study building - Configuration

Being built in Pemberton, BC

3 storeys, 15 suites per floor

Parkade below

High performance envelope

Triple pane windows

100% outdoor air ventilation w/ heat recovery

Some heating/cooling in ventilation air

Supplementary baseboard heating

Solar assisted heat pump heat pump hot water with natural gas backup boiler

Case study building - Envelope

Envelope assemblies were chosen by the builder

Walls – Dual walls:

- Outside: structural wood walls with batt insulation
- Inside: steel stud (sufficient for the drywall) with spray foam insulation
- 1” foam filled gap between the two walls.

Roof – Unventilated flat roof with open cell SPF and spray applied vapour barrier, wood truss.

Parkade ceiling – spray foam, steel truss

Parkade walls – Insulated Concrete Forms

Envelope options considered in this study

5 different wall options:

- Outside: 2x6 structural wood wall with fiberglass batt, Inside: Steel stud with 3” of open cell SPF
- Outside: 2x8 structural wood wall with fiberglass batt, Inside: Steel stud with 3” of open cell SPF
- Outside: 2x8 structural wood wall with fiberglass batt, Inside: Steel stud with 4” of open cell SPF
- Outside: 2x6 structural wood wall with fiberglass batt, Inside: Steel stud with 3” of closed cell SPF
- Outside: 2x8 structural wood wall with fiberglass batt, Inside: Steel stud with 4” of closed cell SPF

4 different roof options:

- 4 different thicknesses of open cell spray foam from 12” to 24”

4 different Parkade ceiling:

- 4 different thicknesses of open cell spray foam from 6” to 12”

Gives 80 possible building configurations

Methodology

For every wall/roof/parkade ceiling assembly option:

- Developed equivalent R-values using established methodologies
- Calculated cost

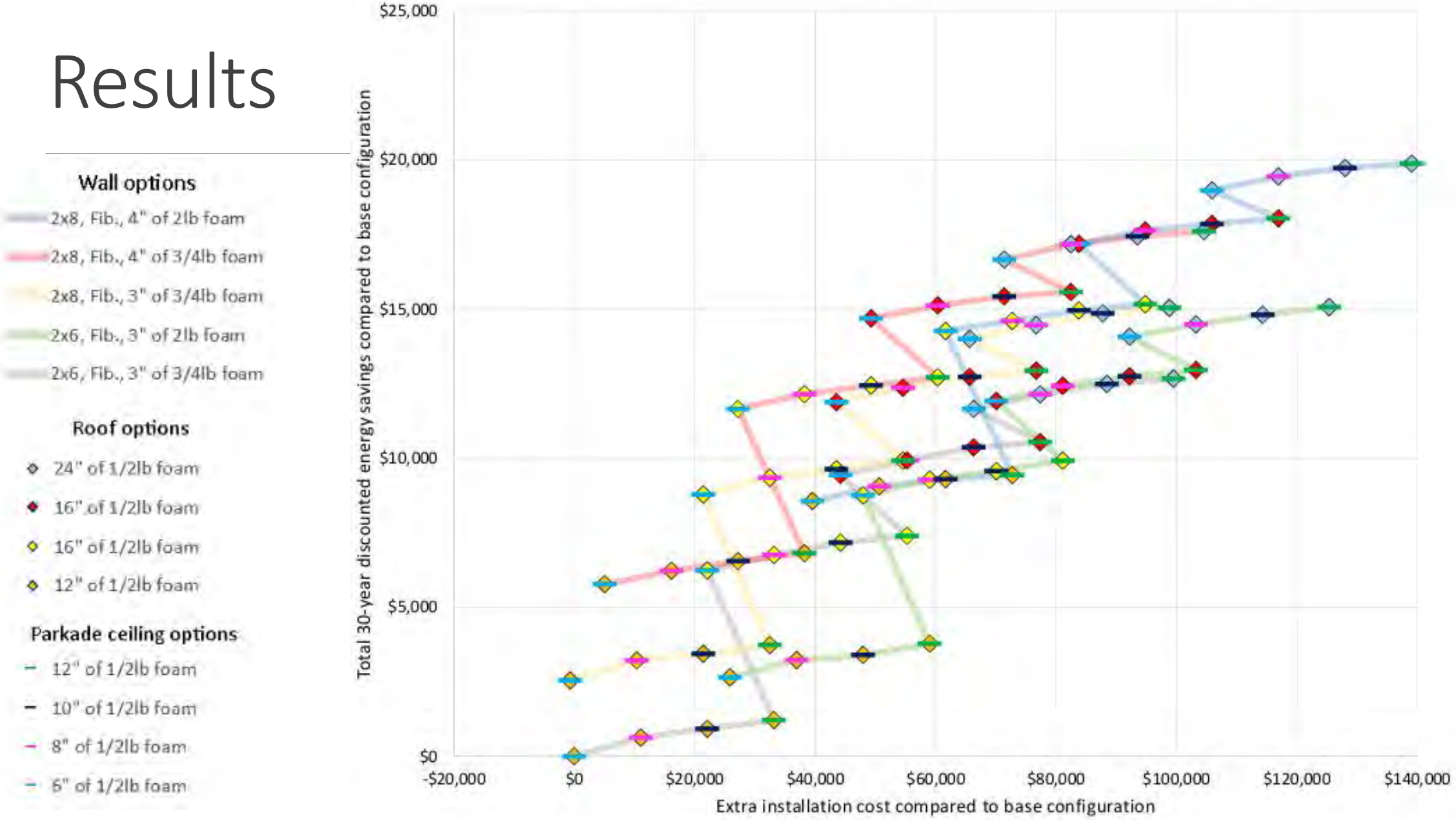
Simulated all possible building configurations

- Used whole-building 8760 hour energy modeling

For each configuration, compared extra energy cost saving (30-year present value) and extra installation cost to the base configuration.

Then, replicated study in excel to compare results.

Results


Wall options
2x8, Fib., 4" of 2lb foam
2x8, Fib., 4" of 3/4lb foam
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Roof options
24" of 1/2lb foam
16" of 1/2lb foam
16" of 1/2lb foam
12" of 1/2lb foam
Parkade ceiling options
12" of 1/2lb foam
10" of 1/2lb foam
8" of 1/2lb foam
6" of 1/2lb foam
Total 30-year discounted energy savings compared to base configuration
$25,000
$20,000
$15,000
$10,000
$5,000
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-$20,000
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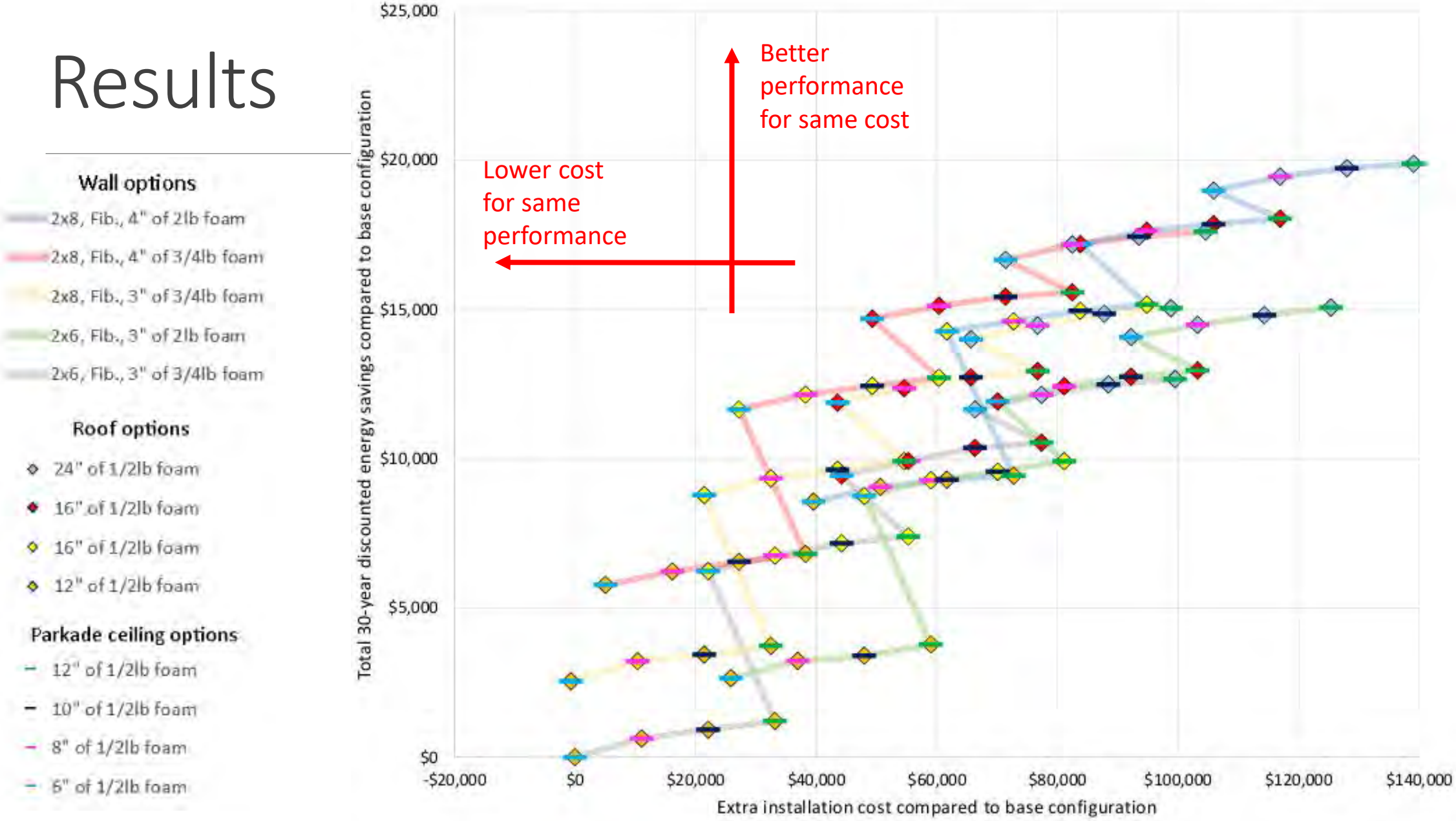
$40,000
$60,000
$80,000
$100,000
$120,000
$140,000
Extra installation cost compared to base configuration

Results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Better performance for same cost
Lower cost for same performance
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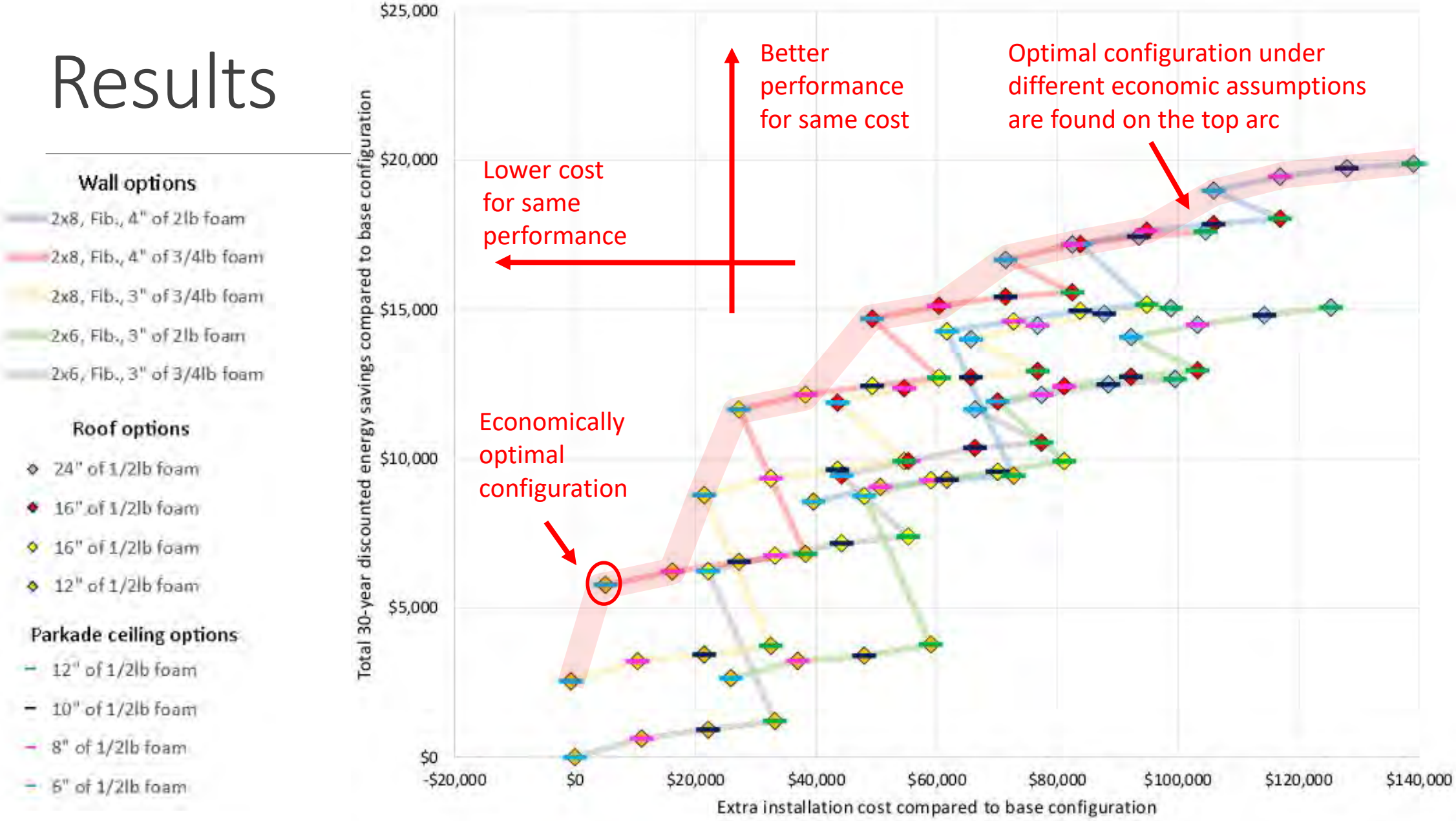
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Extra installation cost compared to base configuration
Better performance for same cost
Lower cost for same performance
Optimal configuration under different economic assumptions are found on the top arc
Economically optimal configuration

Discussion

Found a $50,000 to $70,000 cost difference between configurations with the exact same energy performance

The economically optimal point is quite low

- Partially due to minimum acceptable options set by the builder.
- Note that because of minimum options, the true economically optimal point might not be on the graph

For this building, clear direction is provided by the graph:

- All of the best options use a 2x8 exterior wall
- Economically optimal point uses the second best wall and the worst roof / parkade ceiling

Replication with excel - methodology

Used a bin method calculation

- Split year into temperature bins of 0.1°C by number of hours

Simplified calculation by disregarding elements including:

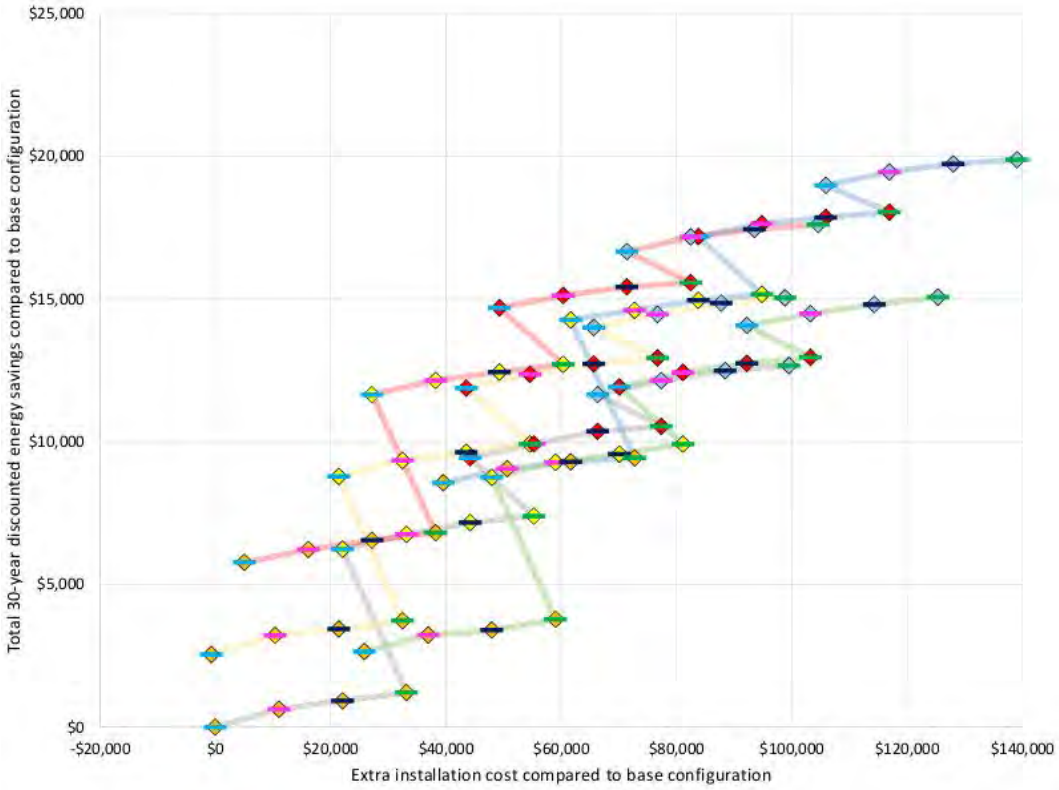
- Solar gain
- Thermal mass
- Internal gains schedules
- Dynamic heat pump efficiency

Calculated energy balance for each temperature bin

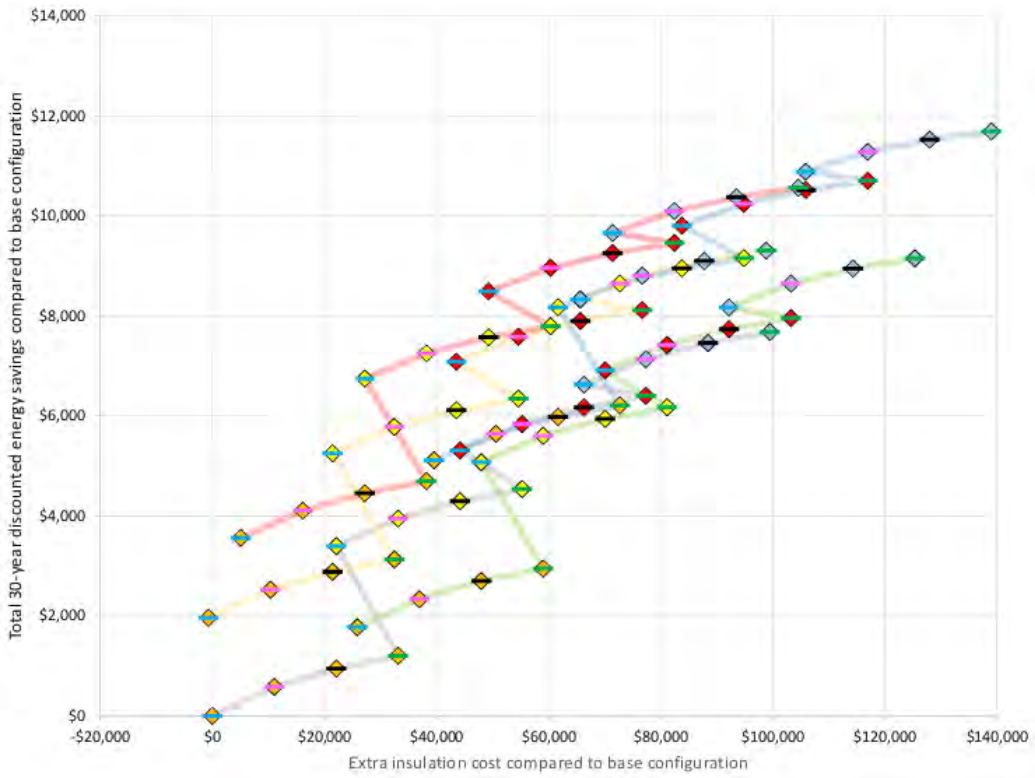
- Disregarded bins with no heating requirements

Replication with excel - Results

Whole building energy modeling results



Excel results



Replication with excel - Discussion

Excel identified the same optimal configurations

Excel did not identify the same magnitude of cost savings

Modifying the calculation assumptions changes the magnitude of the savings:

- Decreasing the mechanical efficiency assumption increases the magnitude of savings
- Decreasing the miscellaneous energy assumption increases the magnitude of savings

Improving the excel calculation by including solar gain, schedules, thermal mass, HVAC efficiency estimates, etc. would improve the excel results

Conclusions

Significant installation cost savings can be obtained for a given level of performance by intelligently assigning the installation budget.

Economically optimal configuration identified

Potentially optimal configurations under different energy cost assumptions also identified

Methodology would be relatively low effort if:

- The energy model was already built for other purposes, and
- Assembly effective R-values could be calculated from tabulated data

Replication in excel showed that the same configurations were identified, but not the magnitude

- Magnitude could be improved with a better calculation.
- Excel would be appropriate where magnitude is not important - such as a builder with fixed budget for envelope upgrades above code minimum.

Thank you

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Questions?