A Reality-Based Cost-Benefit Analysis of High Performance Buildings in Victoria, BC

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University of Victoria

Introductions

ERIC WILSON
B.Eng, MASc, EIT

PROFESSIONAL EXPERIENCE

University of Victoria, PhD Candidate

- Exploring the importance of empathetic design in engineering solutions to “wicked” problems.

University of Victoria, Laboratory Instructor

- Facilitated learning of approximately 400 students in two first year engineering design courses.

University of Victoria, MASc Candidate

- Explored the impacts of Step Code on the cost and energy performance of residential construction projects in Victoria, BC.

Read Jones Christoffersen, Design Engineer

- Involved in a range of projects ranging from building retrofits to product design.

Cali Construction, Skilled laborer

- Gained hands-on skills in many aspects of home building

Presentation Structure

- Project Description
- Project Purpose
- Importance to Industry
- Methodology
- Results
- Conclusions (three main take aways)
- Project Limitations

Duration: 15 minutes

I can answer any questions next to the poster that showcases my work

Project Description

- Partnership between the University of Victoria, Read Jones Christoffersen, and MITACS.
- Research was conducted between 2016 and 2017.
  - SCIWG was still finalizing Step Code.
- Case study analysis of as-built high-performance building in Victoria, BC.

CIVIL ENGINEERING

Project Description

Project Purpose

- Explore energy advantage and cost challenge of high performance residences.

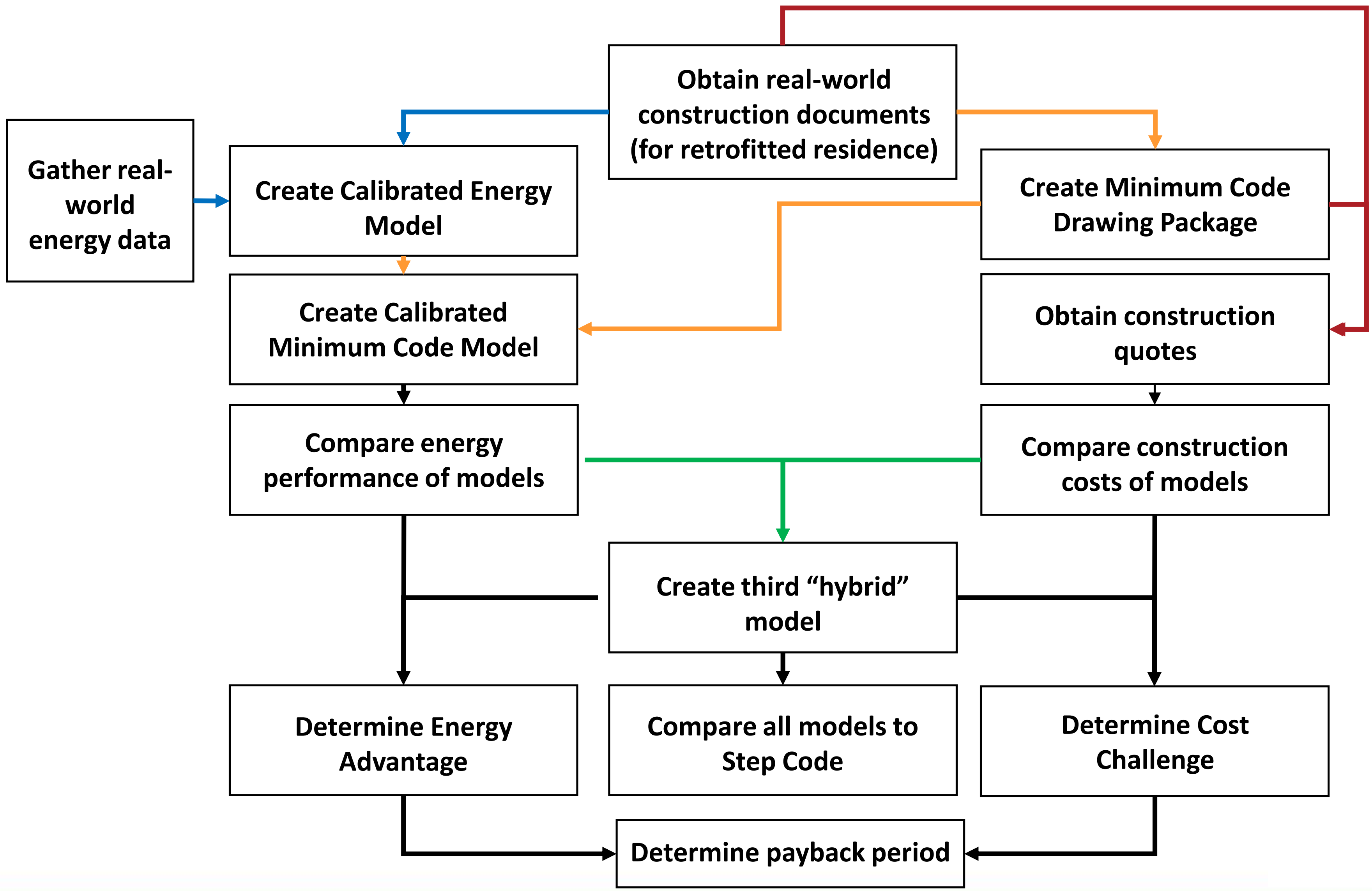
Issues and challenges explored:

1. Determine what Step level a case-study residence achieved.
2. Explore the energy savings for the case study residence.
3. Determine the cost challenge of the case-study residence.
4. Explore how long it will take to recoup costs from building to performance tiers.

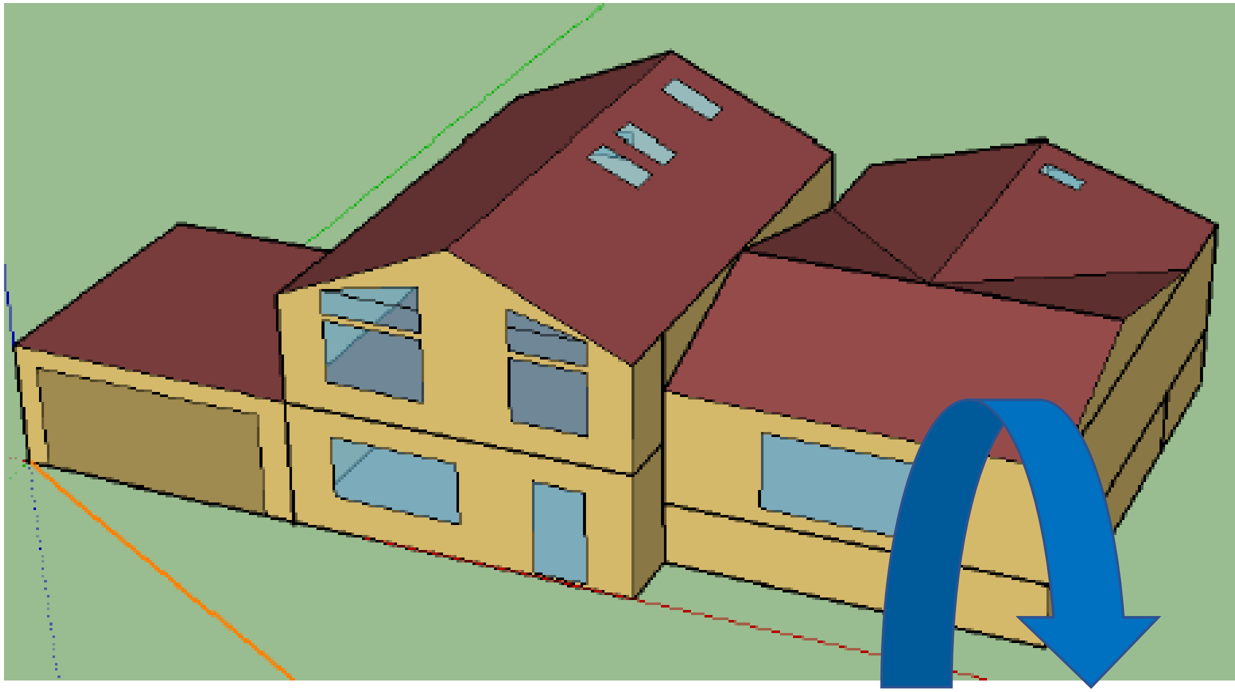
Project Importance

- Research into a new subject area.
  - limited research had been done on this subject when this project was underway in 2016/2017.
- Benchmark to home builders.
- Real-world cost-benefit analysis.

Methodology



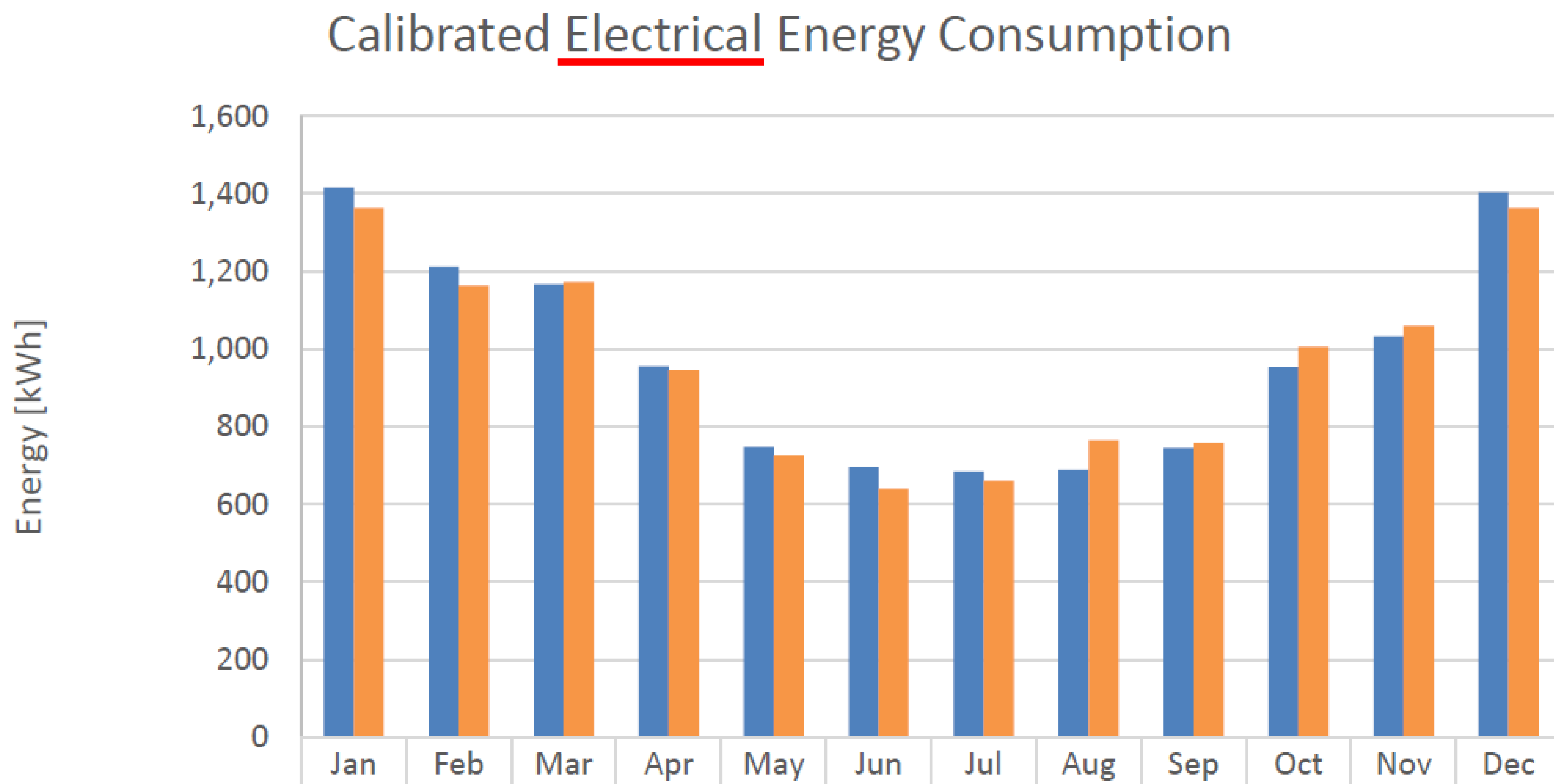
Results and Discussion



Assembly	RSI - Modelled	RSI - Calculated	% Diff
EW1	3.82	3.8	-0.52
EW2	3.63	3.73	2.75
R1	6.44	6.32	-1.86
R2	5.85	5.84	-0.17

*Note: Window U-values were specified within OpenStudio

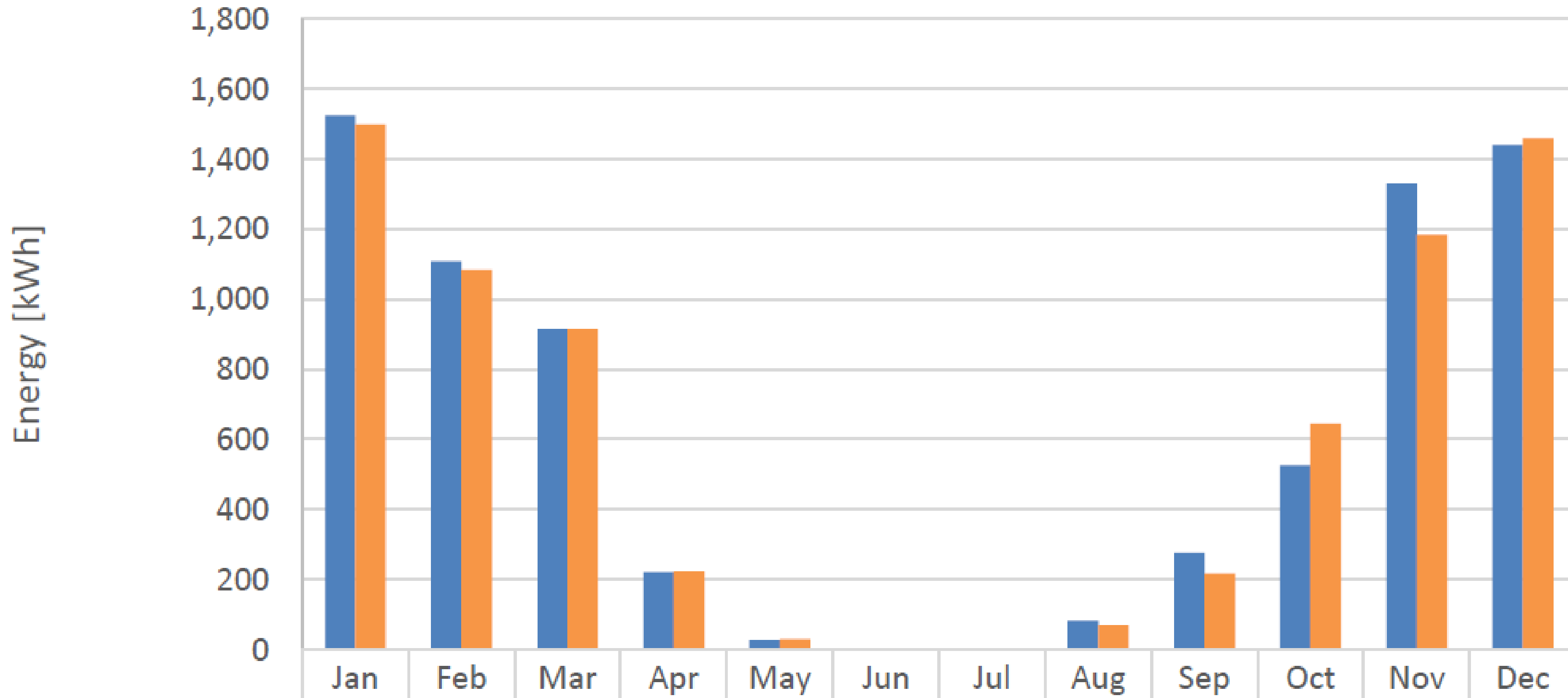
Results and Discussion



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual [kWh]	1,415	1,211	1,166	955	748	696	684	689	745	953	1,032	1,403
Modelled [kWh]	1,362	1,163	1,171	945	725	640	660	764	758	1,006	1,060	1,363

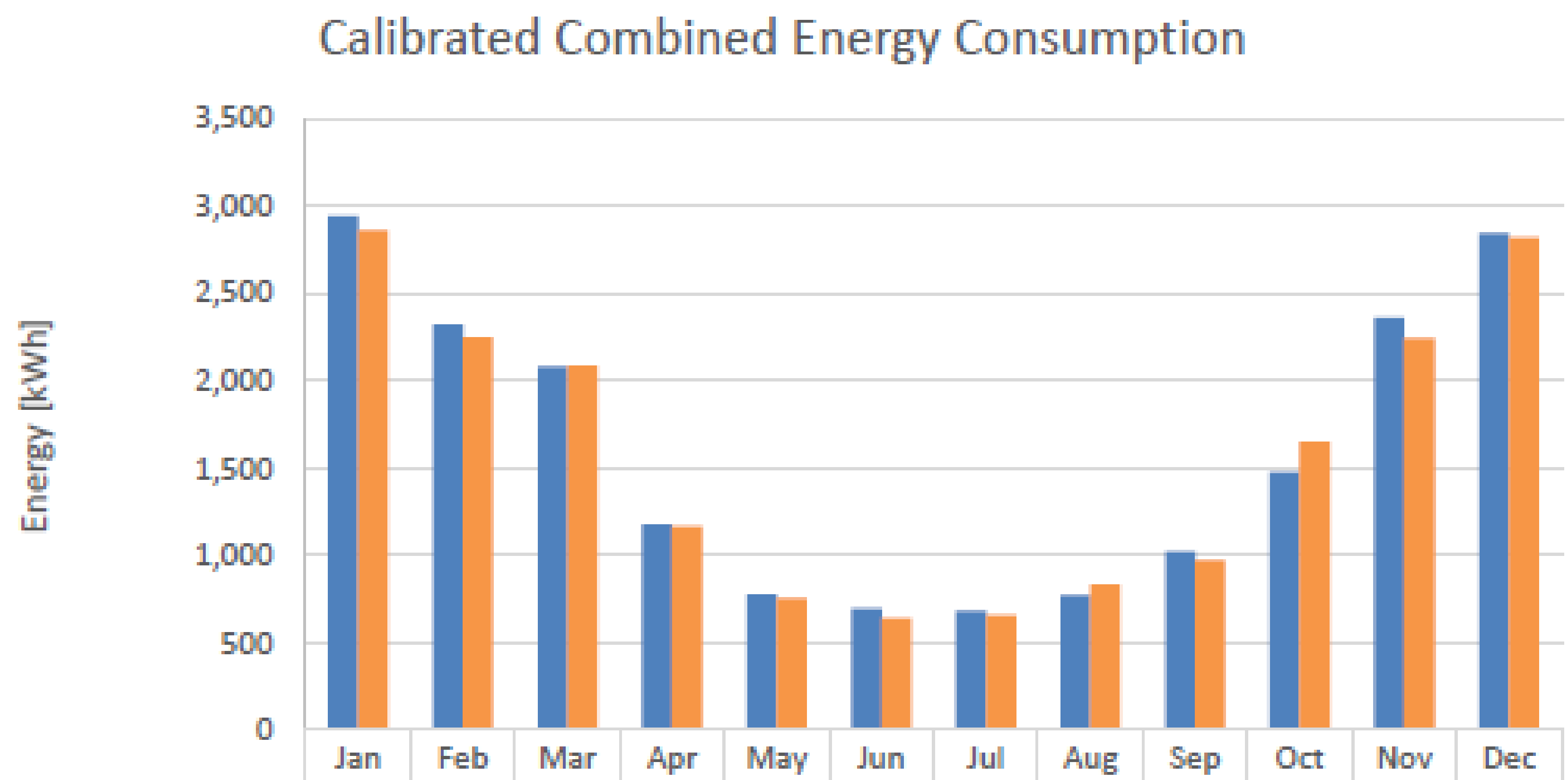
Results and Discussion

Calibrated Heating Energy Consumption



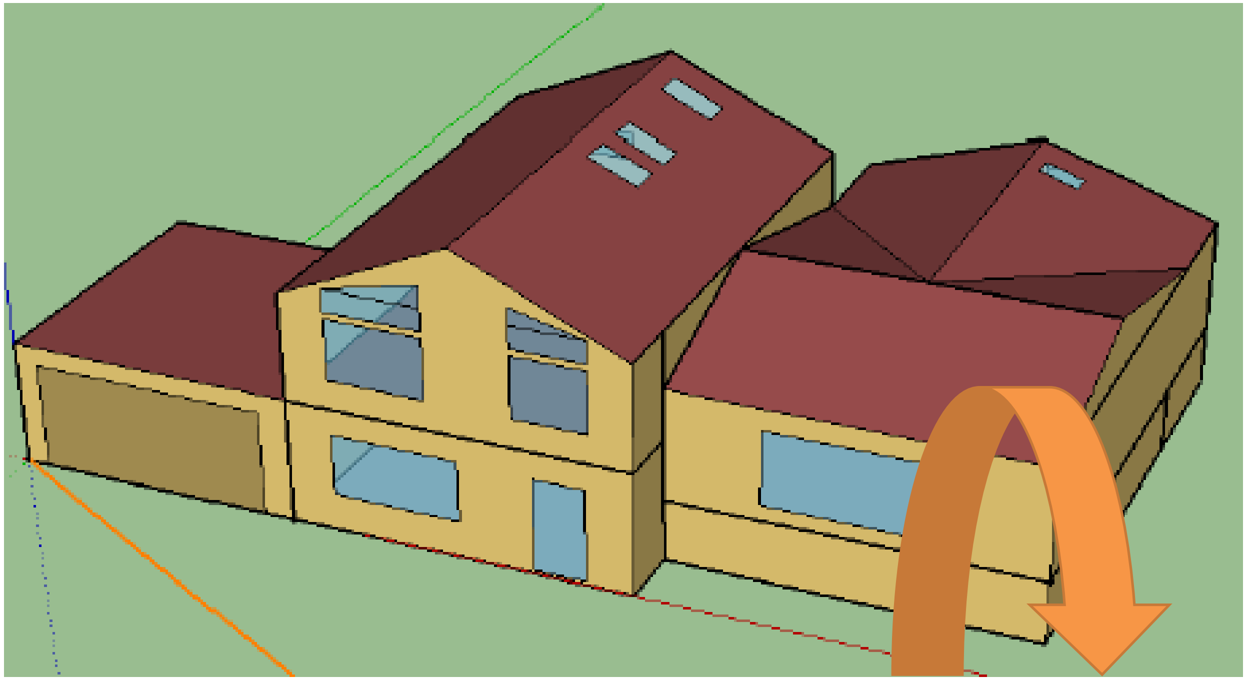
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual [kWh]	1,524	1,108	914	222	28	0	0	83	277	526	1,330	1,440
Modelled [kWh]	1,499	1,083	914	224	30	0	0	69	217	645	1,184	1,459

Results and Discussion



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Actual [kWh]	2,939	2,319	2,080	1,177	776	696	684	772	1,022	1,479	2,362	2,843
Modelled [kWh]	2,861	2,246	2,085	1,169	755	640	660	833	975	1,651	2,244	2,822

Results and Discussion



Electrical Equipment Schedule

Lighting Schedule

Heating Set Points

Service Water Schedule

Building Orientation

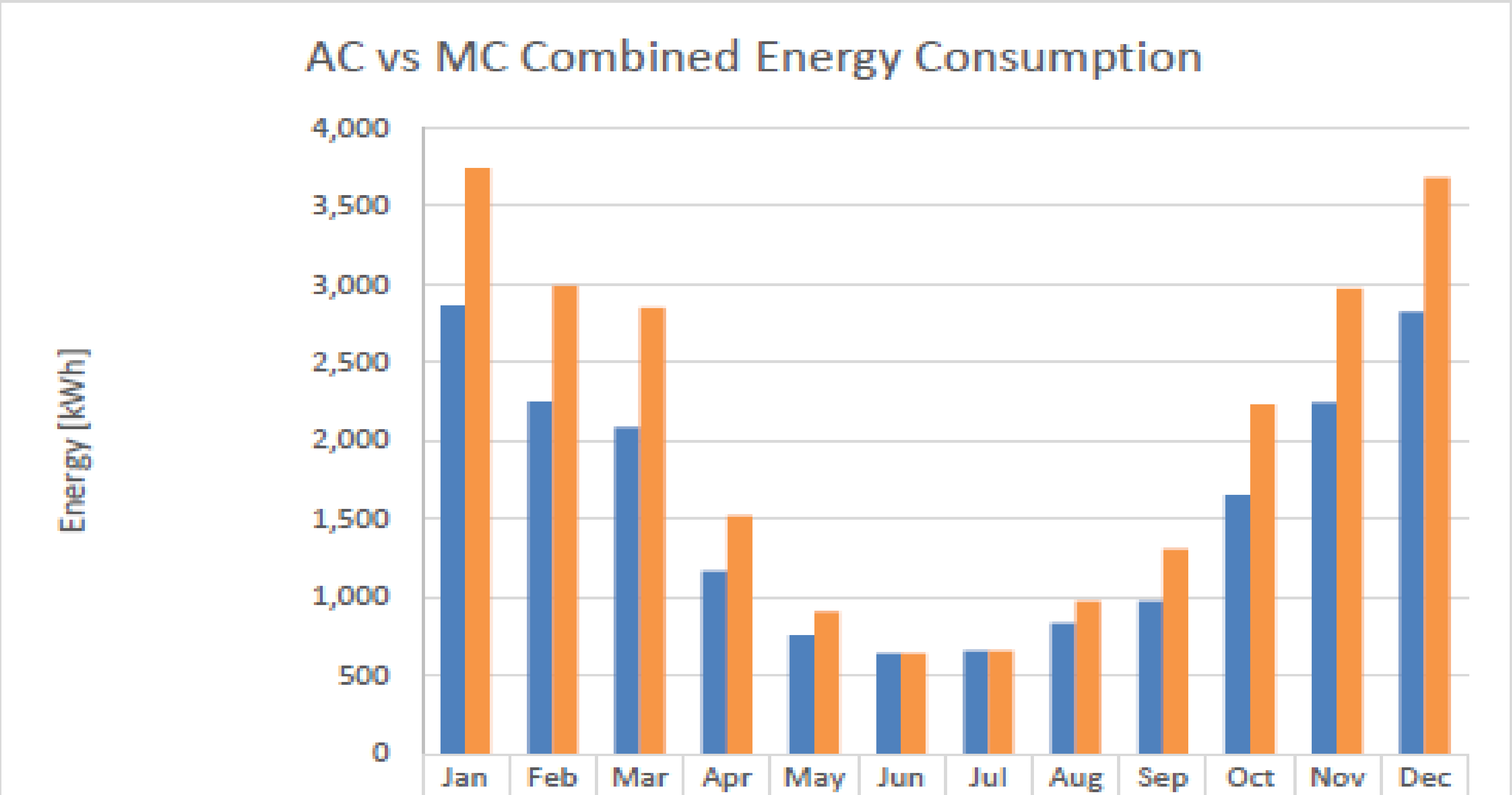
Construction Sets

Air Tightness

BCBC Code Minimums

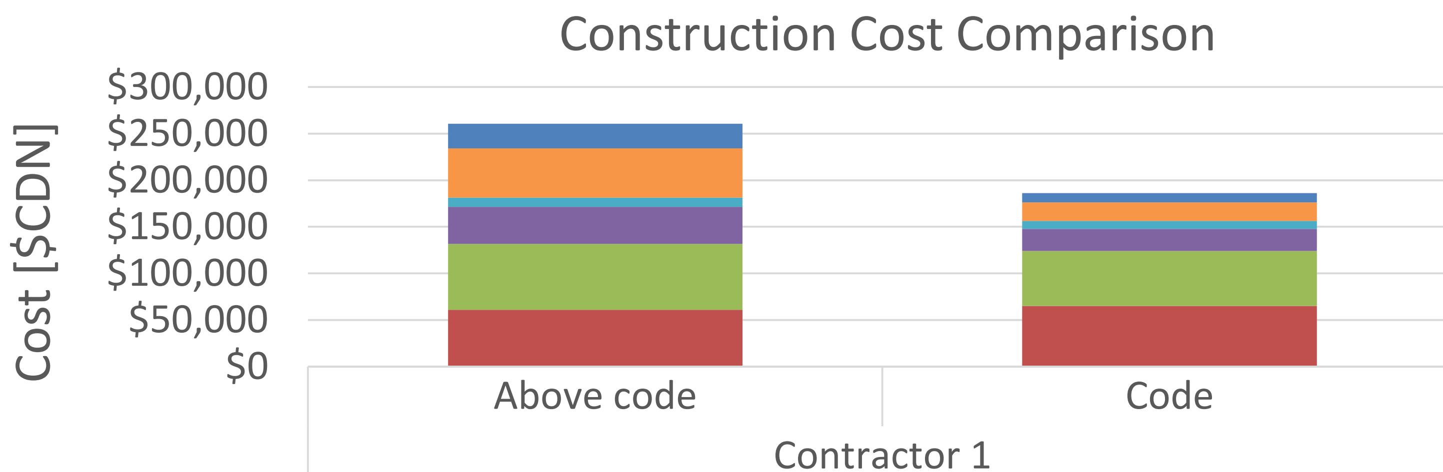
Assembly	RSI - Modelled	RSI - Calculated	% Diff
EW1 - Typical exterior walls	2.76	2.78	-0.72
EW2 - Insulated foundation walls	1.91	1.99	-4.19
R1 - Cathedral roof and garage roof	4.7	4.67	0.64
R2 - Typical trussed roof	6.94	6.91	0.43

Results and Discussion



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Above Code [kWh]	2,861	2,246	2,085	1,169	755	640	660	833	975	1,651	2,244	2,822
Minimum Code [kWh]	3,740	2,988	2,851	1,520	911	640	660	973	1,309	2,228	2,972	3,679

Results and Discussion

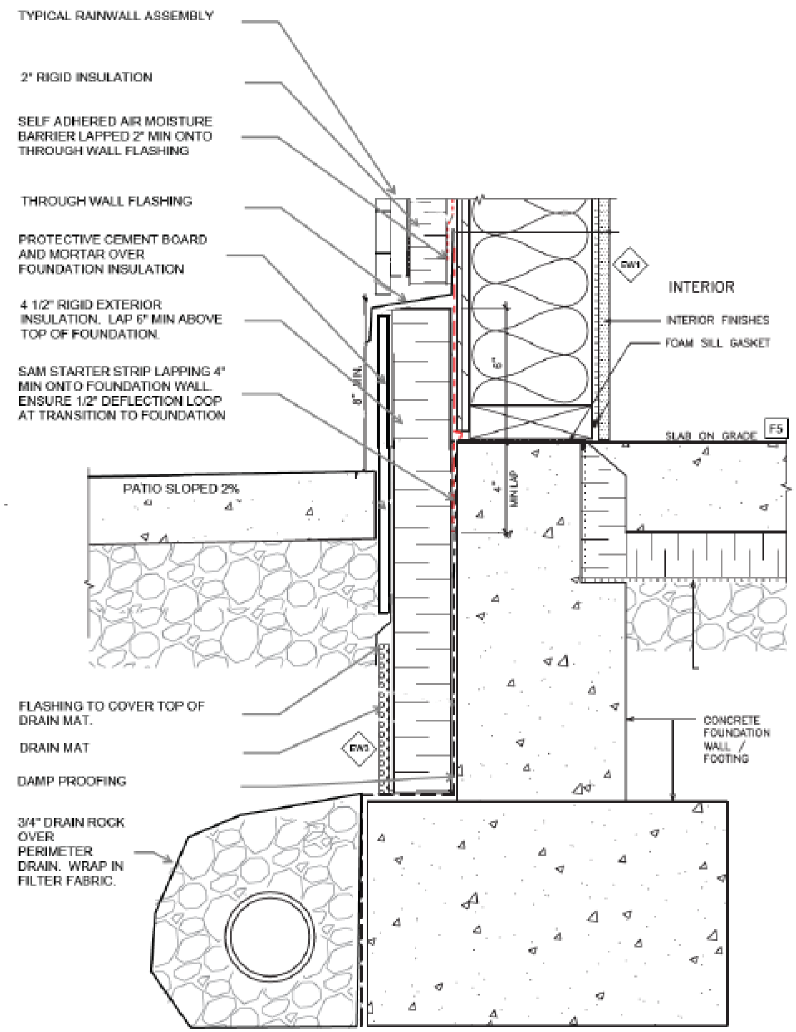


	Above code	Code
Windows	$26,500	$9,872
Roof assemblies	$52,580	$19,921
Interior wall assemblies	$10,049	$8,554
Floor assemblies	$39,733	$23,874
Exterior wall assemblies	$70,860	$58,749
Framing	$60,844	$65,197

CONSTRUCTION COST COMPARISON EXCLUDING $183,340 IN FIXED COSTS

Cost Challenge: $7,759

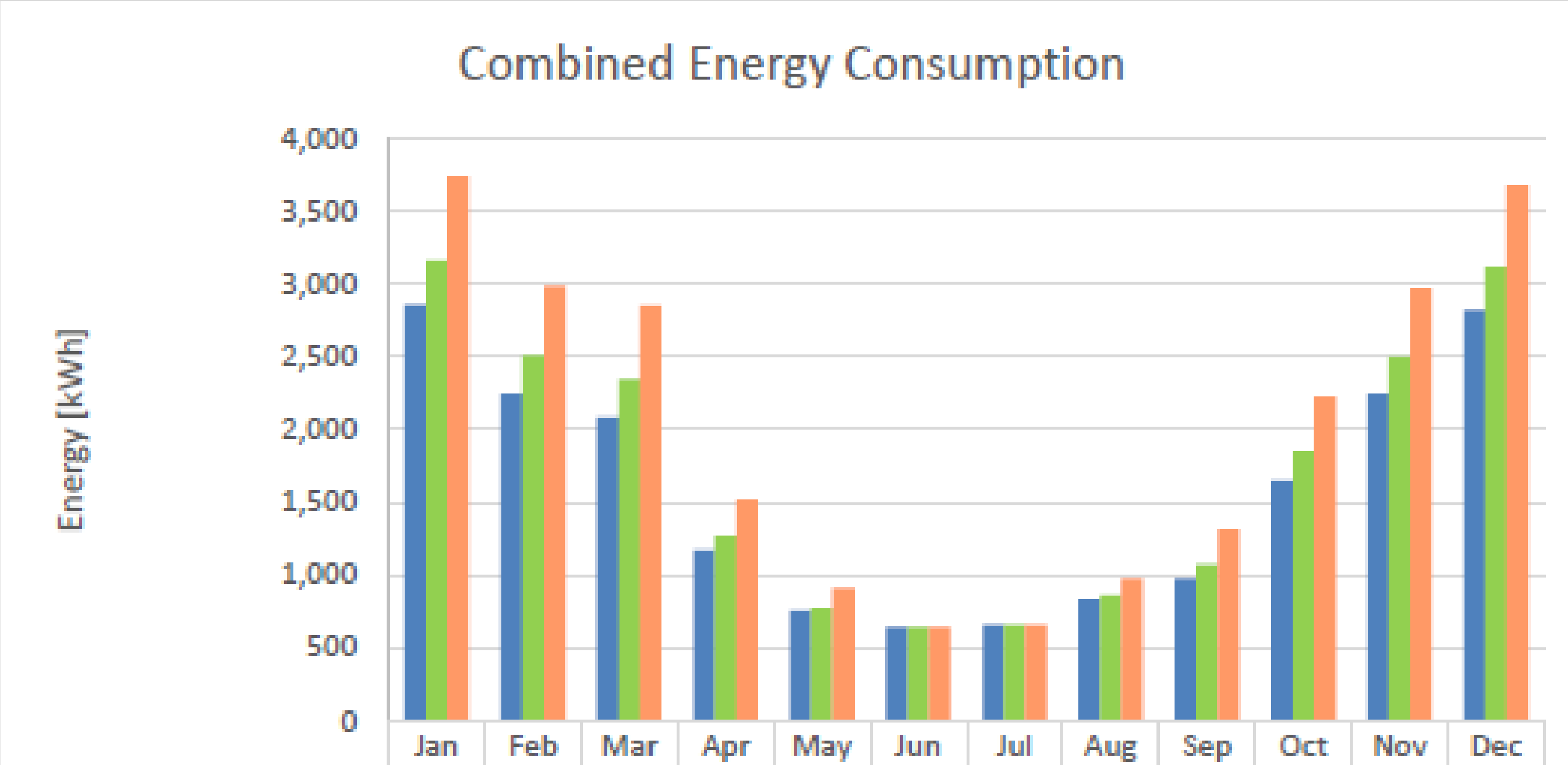
Results and Discussion



EW1	EXTERIOR WALL 2X4	RSI	R
1	FINISH TO OWNERS SPECIFICATION	0 00	0 00
2	1/2" GYPSUM WALL BOARD	0 08	0 45
3	2X4 STUDS	0 00	0 00
4	3 5" ROXUL COMFORTBATT INSULATION	1 93	10 9
5	1/2" PLYWOOD SHEATHING	0 11	0 62
6	SOPRASEAL STICK V P A/M BARRIER	0 00	0 00
7	2" ROXUL COMFORTBATT IS	1 41	8 01
8	1/2" RAINSCREEN/CAPILLARY BREAK	0 17	0 97
9	WOOD SIDING OR FIBRE CEMENT CLADDING	0 10	0 57
EFFECTIVE RSI / R VALUE OF ENTIRE ASSEMBLY		3 80	21 6

EW3	EXT. WALL - 6" CONC. WALL	RSI	R
1	DUROCK CEMENT BOARD	0.07	0.39
2	DORKEN "DELTA-DRAIN" DRAINBOARD	0.05	0.28
3	4.5" ROXUL COMFORTBOARD 80 INS.	3.17	18.0
4	SOPREMA COLPHENE LM 300 MEMBRANE	0.00	0.00
5	6" CONCRETE FOUNDATION WALL	0.20	1.15
EFFECTIVE RSI / R VALUE OF ENTIRE ASSEMBLY		3.49	19.8

Results and Discussion



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Above Code [kWh]	2,861	2,246	2,085	1,169	755	640	660	833	975	1,651	2,244	2,822
Hybrid Model [kWh]	3,166	2,510	2,344	1,270	769	640	660	861	1,075	1,850	2,499	3,118
Minimum Code	3,740	2,988	2,851	1,520	911	640	660	973	1,309	2,228	2,972	3,679

Results and Discussion

	Cost Challenge [$]	Energy Advantage [kWh]
ACR	$85,278.50	5500
HR	$7,759.00	3711

67% of the Energy Advantage for 9% of the Cost Challenge

Results and Discussion

Minimum code

Hybrid Model

Above code

Step Level	Energy Modelling	Airtightness	Mechanical Energy Use	Envelope
Step 1 Enhanced Compliance (BC Building Code Performance)	Required	3.5 ACH_{50}	BCBC using 9.36.5. or ERS v15 ref. house (MEUI of 80 kWh/m^2/year is likely, but not required)	Report on TEDI and PTL (Peak Thermal Load) (TEDI 50 kWh/m^2/year is likely, but not required)
Step 2 10% Beyond Code	Required	3.0 ACH_{50}	10% better than ERS v15 ref. house OR MEUI – 60 kWh/m^2/year	TEDI – 45 kWh/m^2/year OR PTL – 35 W/m^2
Step 3 20% Beyond Code	Required	2.5 ACH_{50}	20% better than ERS v15 ref. house OR MEUI – 45 kWh/m^2/year	TEDI – 40 kWh/m^2/year OR PTL – 30 W/m^2
Step 4 40% Beyond Code	Required	1.5 ACH_{50}	40% better than ERS v15 ref. house OR MEUI – 35 kWh/m^2/year	TEDI – 25 kWh/m^2/year OR PTL – 25 W/m^2
Step 5	Required	1.0 ACH_{50}	MEUI – 25 kWh/m^2/year (no ERS option)	TEDI – 15 kWh/m^2/year OR PTL – 10 W/m^2

Results and Discussion

Simple Mortgage Case

- Fixed mortgage rate of 3.64%
- Amortization period of 25 years
- Fixed energy costs

	MCR	HR
Total Building Cost	$369,507.00	$377,266.00
Monthly mortgage	$1,872.25	$1,911.56
Yearly energy consumption [kWh]	24472	20761
energy cost $/kWh	$0.11	$0.11
Energy cost / yr	$2,691.92	$2,283.71
Energy cost / mn	$224.33	$190.31

HR versus MCR	
Energy savings /mn	$34.02
Additional mortgage cost	$39.31
Percentage covered by energy savings	87%

Results and Discussion

Derived Amortization Equation

$$t_N = \frac{\ln\left[\frac{C_C \ln(1+r)}{E_A P_{f(0)}} + 1\right]}{\ln(1+r)}$$

Where:

- t_N = Payback Period
- C_c = Cost Challenge
- E_A = Energy Advantage
- $P_{f(0)}$ = Cost of energy at t = 0
- r = Energy cost inflation rate

Conclusions

Three takeaways:

1. Step 3 compliance was achieved for an additional cost of $7,759.
2. Energy savings cover 87% of the increase in mortgage costs.
3. The myth that you need triple-glazed windows to meet Step-3 performance is not *always* true.
    - Determine this on a case-by-case basis

Limitations

1. The "optimization" was fairly limited in its sophistication.
   - Parametric study or Genetic Algorithm could likely improve this model further.
2. Amortization time is very sensitive to fuel cost. (*eg.* Electricity vs Natural Gas)
   - This makes energy improvements less appealing from a pay-back perspective if energy is cheap.

Thank you !

I would be happy to discuss any questions beside my poster presentation.