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Multi-Objective Decision Making Optimization of a Residential Net Zero Energy Building in Cold Climate

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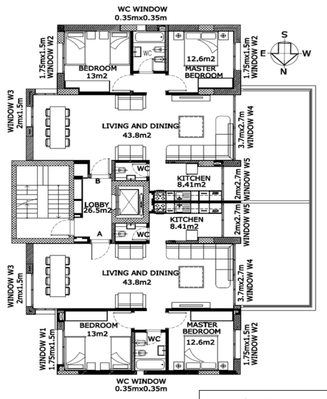
Introduction-Objective

Net Zero Energy Buildings (NZEBs) are suggested to limit buildings energy consumption.

Our Aim

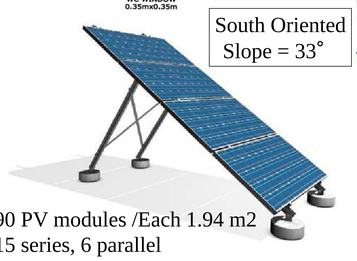
Investigate Cost-effective design options of a residential NZEB in Cedars, through a Multi-Objective Optimization, followed by a Decision Making

Case Study



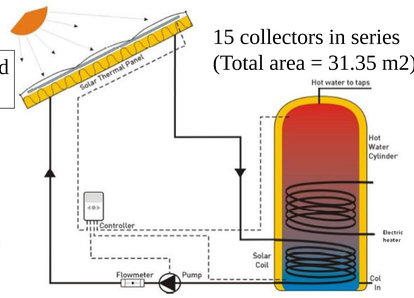
- Three stories building in Cedars.
- Two apartments, each apartment102 m2.
- Heating loads covered by natural gas condensing boiler, η=98.3%, Heating set point = 20˚C
- Flat plate active Solar Domestic Hot Water System + auxiliary Electric heater, to cover domestic hot water demands.
- Photovoltaic system on rooftop to generate electricity.
- Utility power grid for storage.

South Oriented
Slope = 33˚

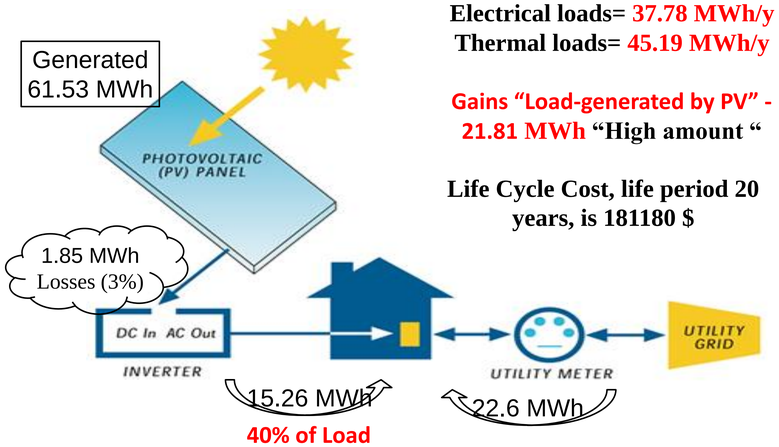


90 PV modules /Each 1.94 m2
15 series, 6 parallel

15 collectors in series
(Total area = 31.35 m2)



Base Case Simulation Results



Electrical loads= 37.78 MWh/y
Thermal loads= 45.19 MWh/y

Gains "Load-generated by PV" - 21.81 MWh "High amount "

Life Cycle Cost, life period 20 years, is 181180 $

Formulation of the optimization problem

Objective functions to Minimize/ Maximize

f1=Min ("Auxiliary electric heater + Pump" consumptions)

f2=Min (Thermal demand)

f3=Min (Difference between load and generation)

f4=Min (Life Cycle Cost)

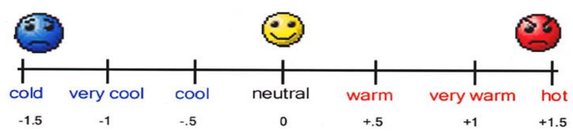
Decision variables

Description	Type	Values	Step
External walls, Roof insulation thickness (cm)	D	1,3,5,7,10	-
Type of double glazing: Krypton or Argon, U-value (W/m².K)	D	0.86, 1.4	-
Cooling set point (˚C)	D	24, 25, 26	-
Heating set point (˚C)	D	19, 20	-
Width window bedroom, master bedroom, kitchen, (m)	C	1 to 2	0.25
Width window Living and dining, (m)	C	1 to 3	0.25
Width window Living and dining, (m)	C	1 to 3.7	0.25
Number of solar collectors in series	C	1 to 20	1
SDHW pump flow rate (Kg/h)	C	50 to 120	5
Number of solar panels in series	C	1 to 20	1
Number of solar panels in parallel	C	1 to 40	1

D: Discrete, C: Continuous

Constraint

Keep Comfort -> Average Predicted Mean Vote |PMV|≤ 0.5



Optimization tool / Algorithm

TRNSYS + MOBO : "Multi-Objective Building Optimization Tool".

The Non-Dominating Sorting Genetic Algorithm (NSGA-II), is adopted.

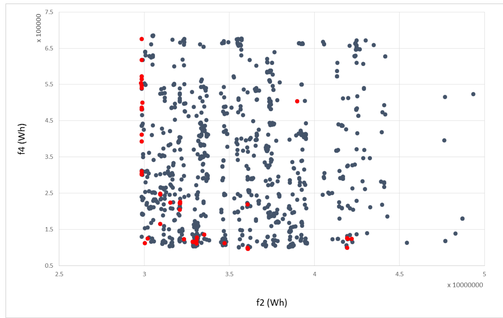
Parameters for NSGA-II:

1- Population size = 40

2- Generation number = 25

Optimization Results-Decision Making

Pareto Front



Four-objective optimization generates Four-dimensional (4D) problem space.

Projecting 4D-Pareto-front on 2D-Graph.

f2: Thermal Load, f4: LCC

Blue: Dominated Variants

Red: Non-Dominated Variants

Multi-Criteria Decision making (MCDM)

Elimination and Choice Expressing the Reality (ELECTRE III) method classifies Pareto front solutions.

Parameters for ELECTRE III:

1-Indeferrence Threshold: 5%

2-Preference Threshold: 10%

3-Veto Threshold: 30%

4-Weights: 25% for each objective function

Decision making Results

	f1 (MWh) "SDHW electric consumption"	f2 (MWh) "Thermal Loads"	f3 (MWh) "Load-generation"	f4 (1000$) "LCC"
Best solution	3.94	30.19	-0.33	124.84
Base case value	4.80	45.19	-21.82	181.18
% difference	17.91	33.19	-98.48	31.09

	Walls insulation	Roof insulation	Windows U-value	Cooling set point	Heating set point
Unit	(cm)	(cm)	(W/m².K)	(˚C)	(˚C)
Optimal	10	10	0.86	25	19
	Solar collectors	Pump flow	Number PV	Eastern WWR	Western WWR
Unit	-	(Kg/h)	-	(%)	(%)
Optimal	8	115	72	21.87	35.15

Conclusions

- **Significant potential to improve energy performance of residential NZEB in cold climate of Cedars by using proven passive strategies.**
- **The optimum design parameters decreases annual thermal load and LCC by 33.19% and 31.09% respectively, compared to the baseline model.**
- **Envelop high level of insulation is a key parameter to decrease the high heating demands.**