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Lebanese University

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

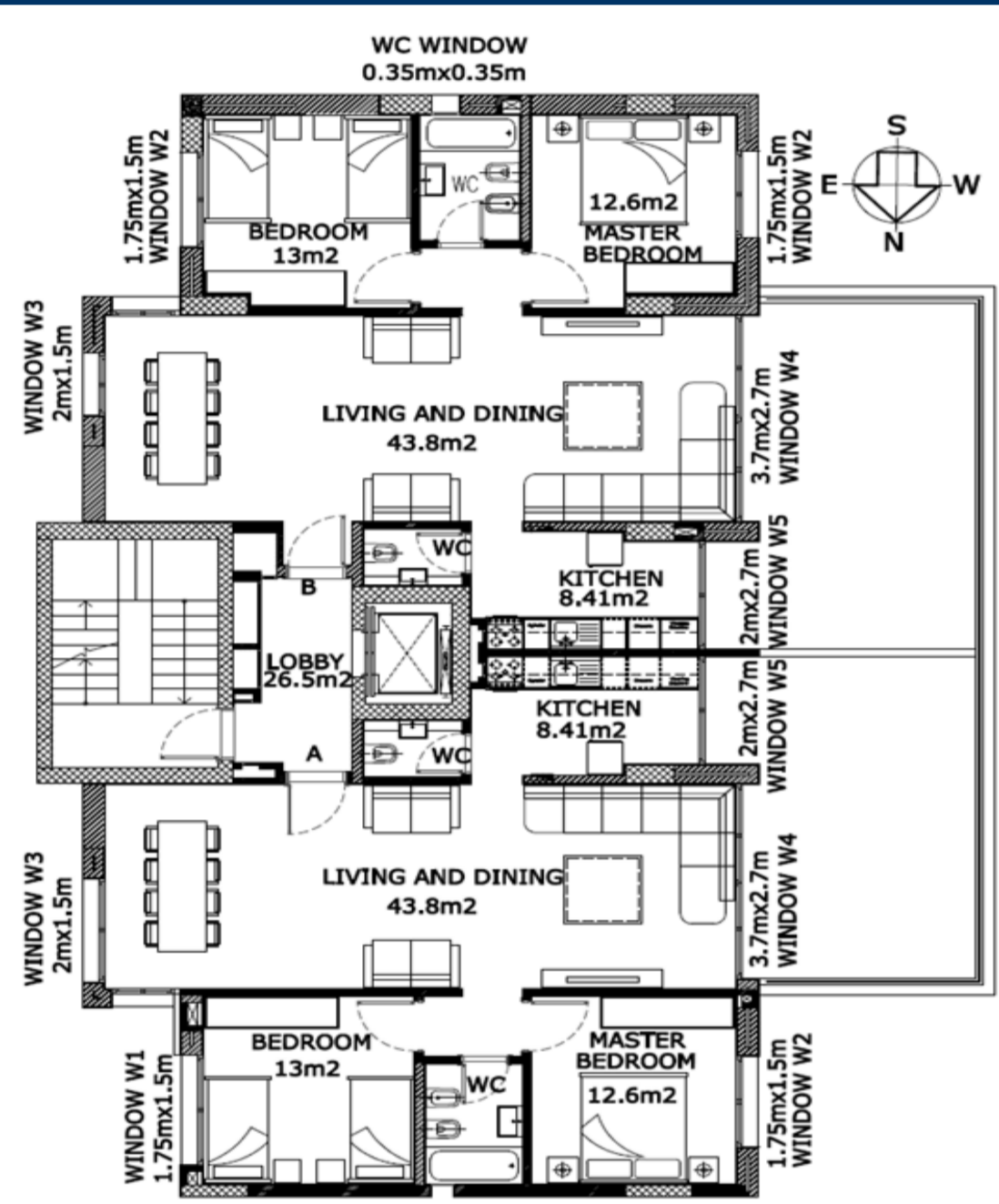
Investigate Cost-effective design options of a residential NZEB in Cedars, through a

ZERO NET ENERGY BUILDING

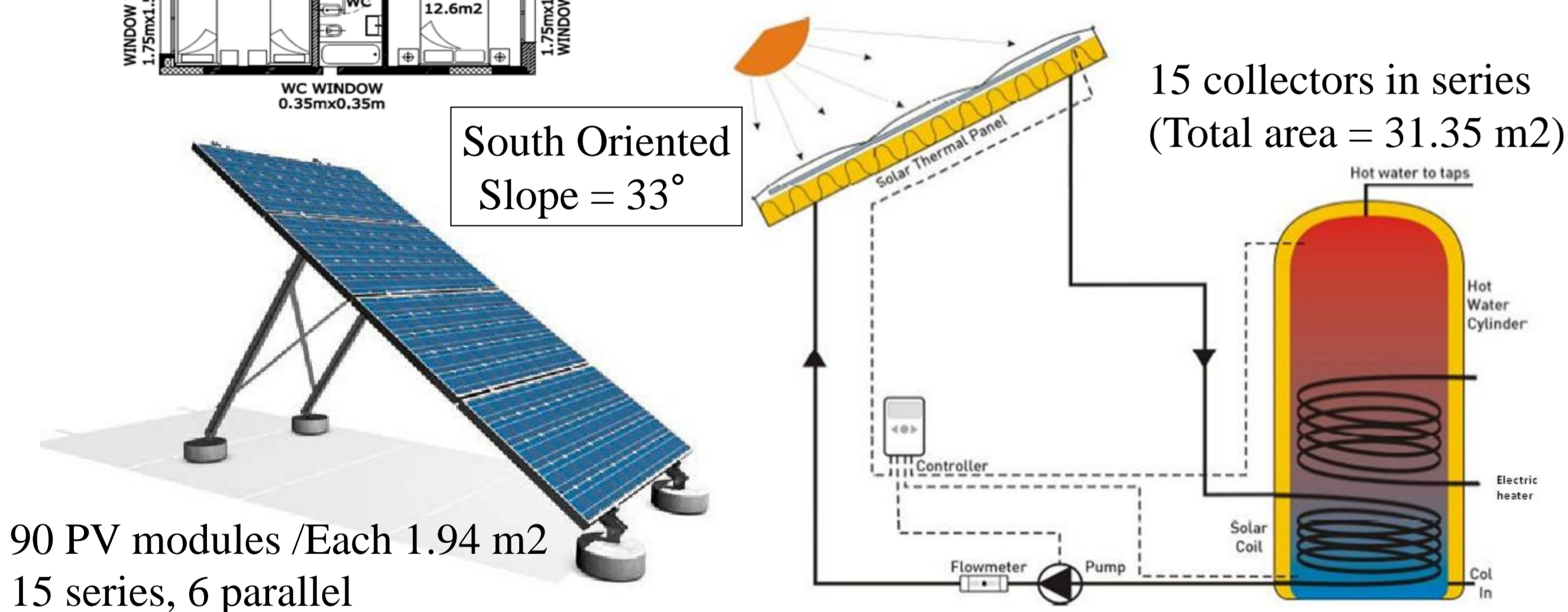


Multi-Objective Optimization, followed by a Decision Making

Case Study



- Three stories building in Cedars.
- Two apartments, each apartment 102 m².
- Heating loads covered by natural gas condensing boiler, $\eta=98.3\%$, 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.

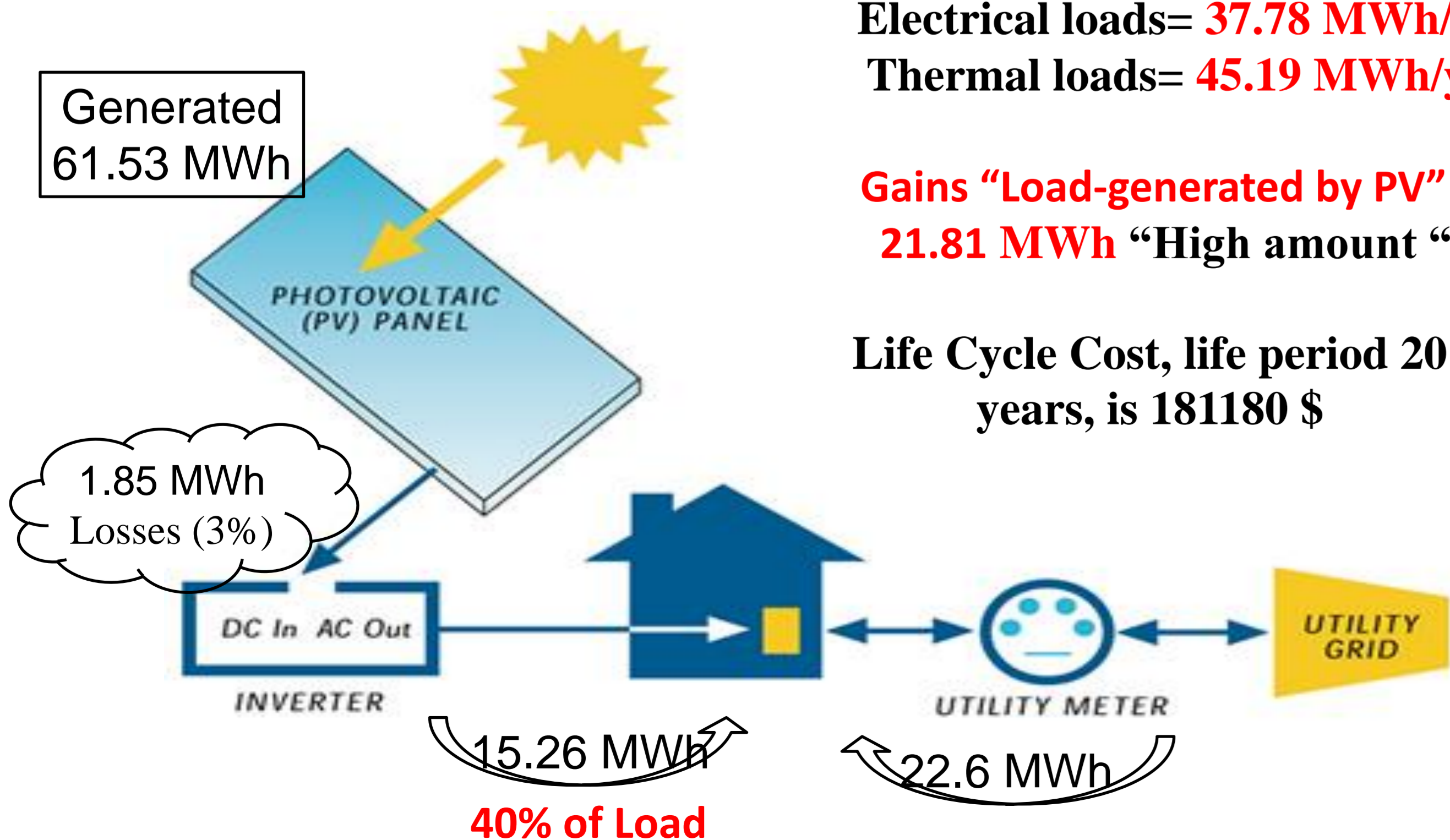


Base Case Simulation Results

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)



OPTIMIZATION



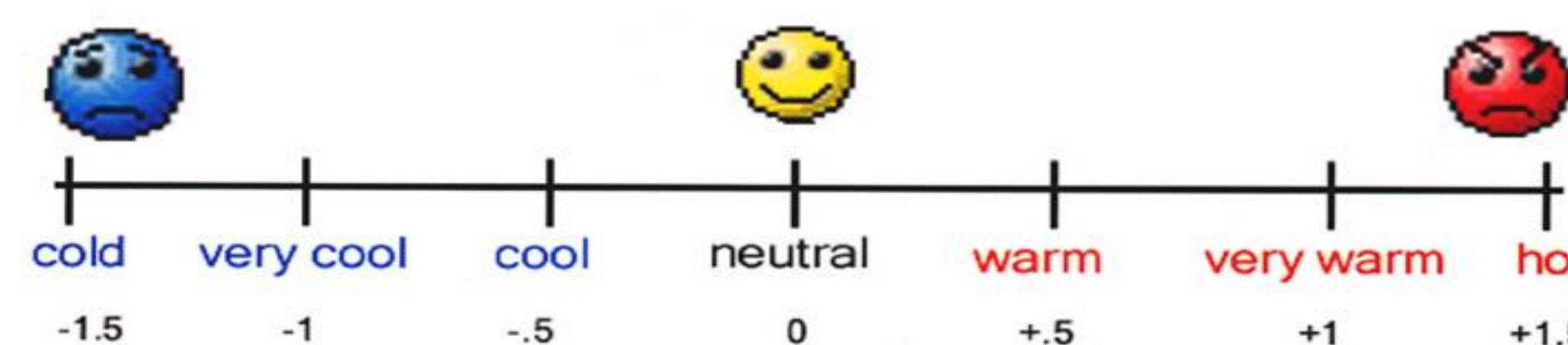
Decision variables

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/m ² .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.

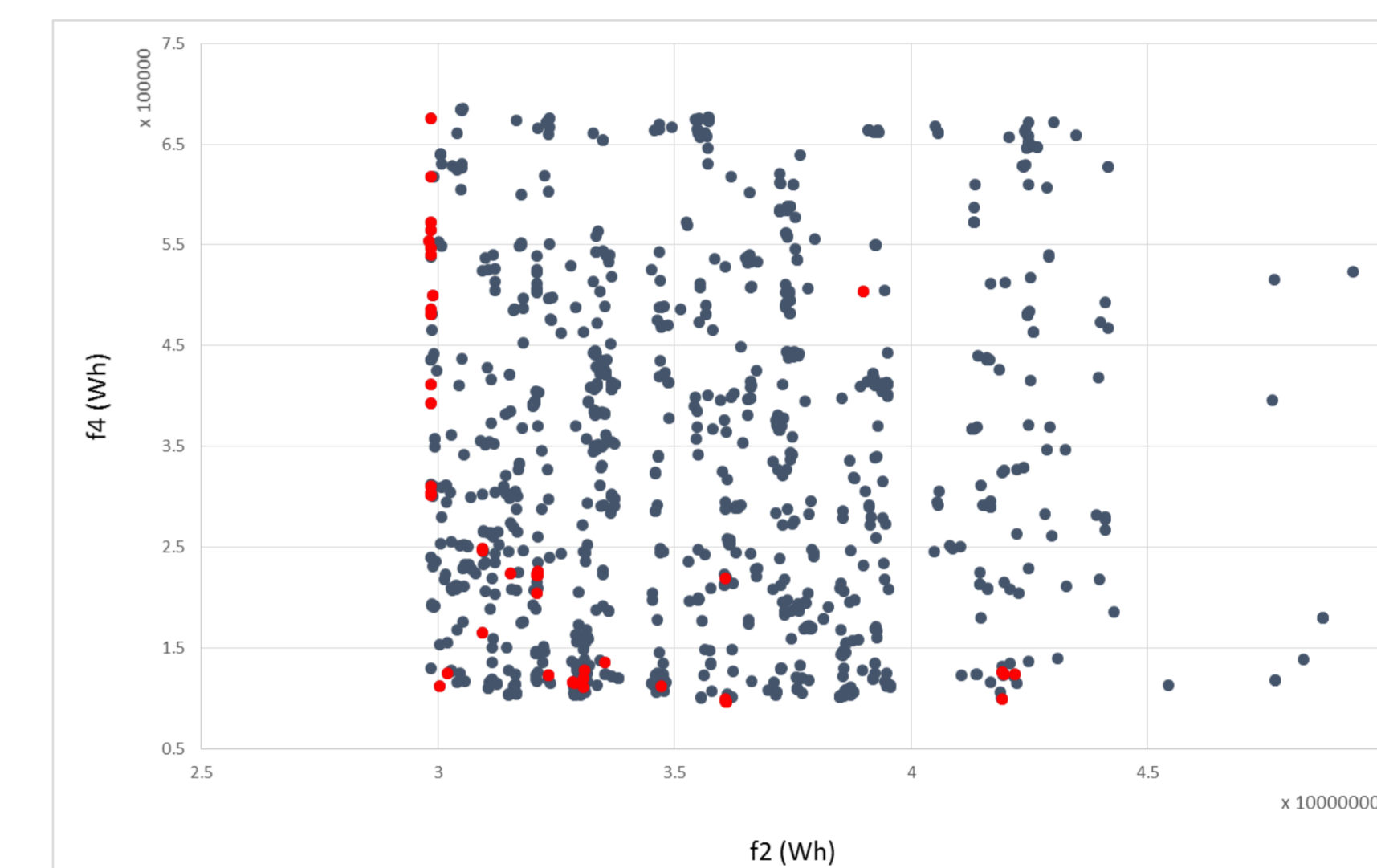
Parameters for NSGA-II:

- 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-Indifference 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 (cm)	Roof insulation (cm)	Windows U-value (W/m ² .K)	Cooling set point (°C)	Heating set point (°C)
Optimal	10	10	0.86	25	19
	Solar collectors	Pump flow (Kg/h)	Number PV	Eastern WWR (%)	Western WWR (%)
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.