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Multi-objective Optimization of Fenestration Design in Residential spaces

The case of MKB, Greenhouse, Malmö, Sweden

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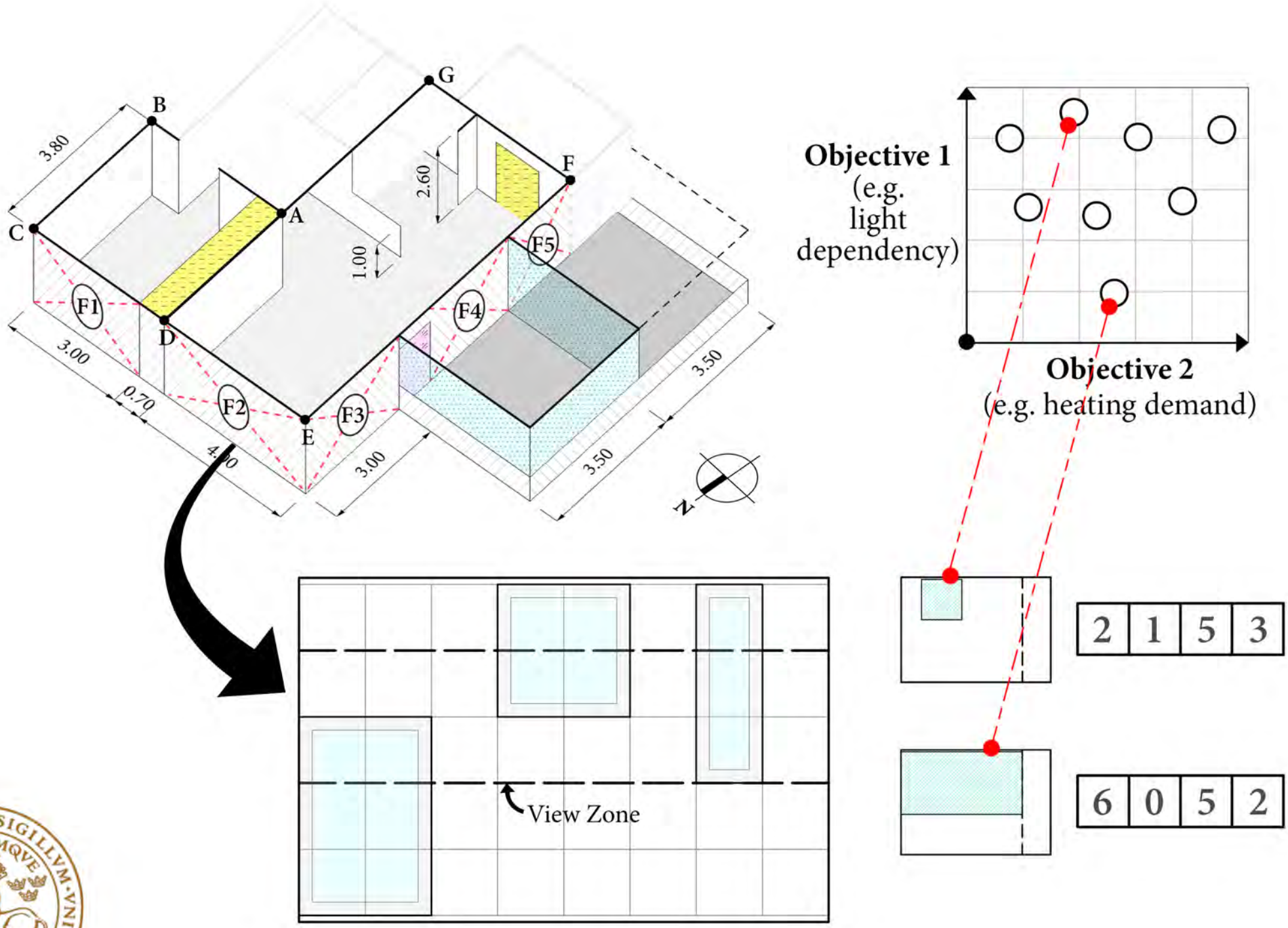

A
B
C
D
E
F
G
F1
F2
F3
F4
F5
3.80
2.60
1.00
3.00
0.70
4.00
3.00
3.50
3.50
N
View Zone
Objective 1
(e.g.
light
dependency)
Objective 2
(e.g. heating demand)
2 1 5 3
6 0 5 2

STUDY OBJECT

(Image: Jaenecke Arkitekter AB)

MKB Greenhouse

Feby Gold

Miljöbyggnad certification
(for daylight)

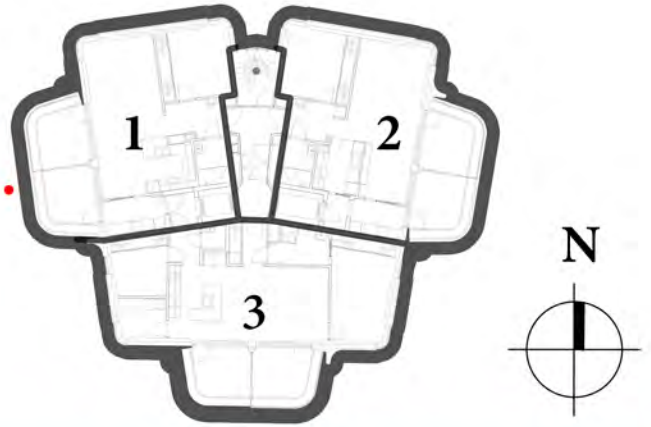
U-value
Walls: 0,15 W/m²K
Windows: 0,80 W/m²K

Infiltration rate: 0,3 l/s/m²

Specific energy use: 48 kWh/m²

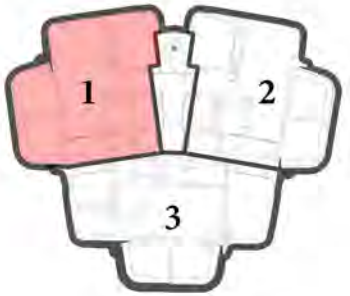
STUDY OBJECT

(Image: Jaenecke Arkitekter AB)

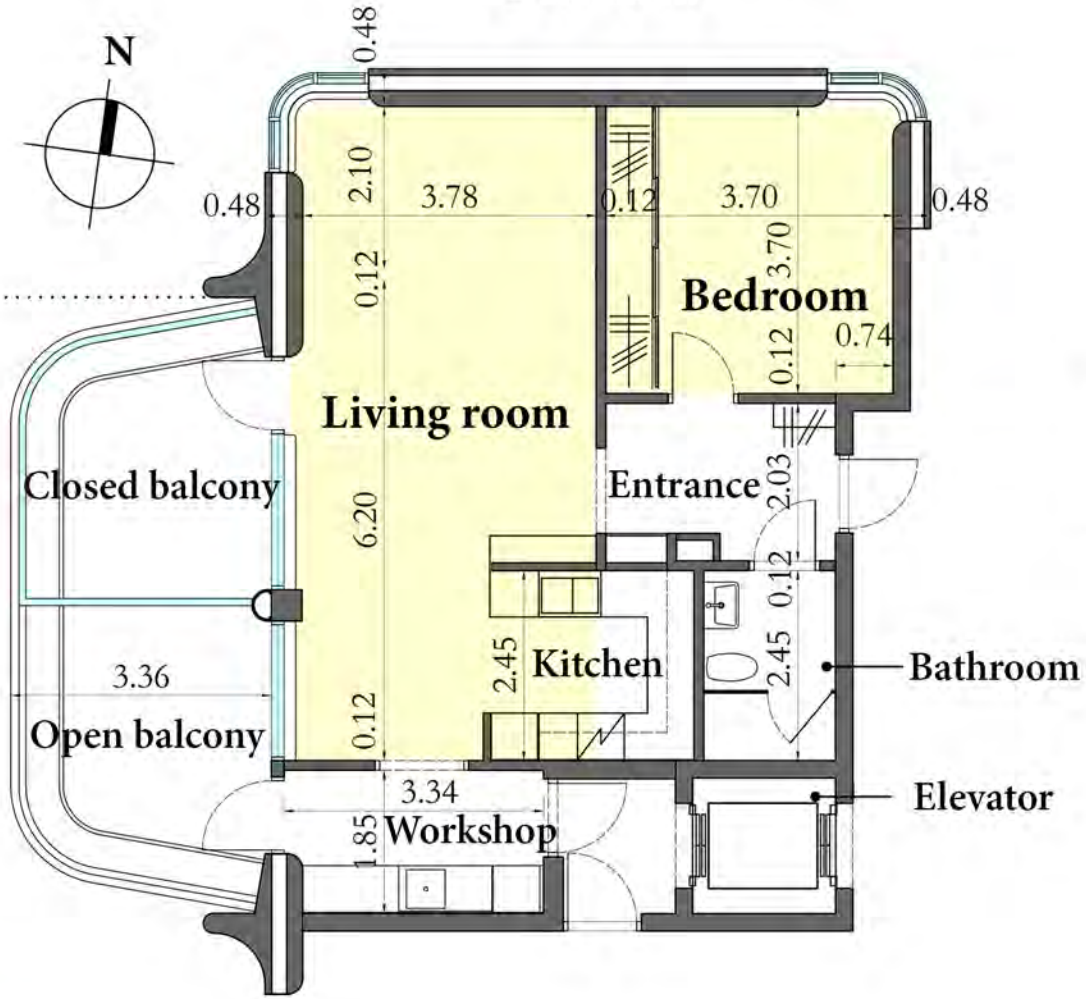


1. Northwest (NW) apartment: 68 m²
2. Northeast (NE) apartment: 68 m²
3. South (S) apartment: 85 m²

STUDY OBJECT



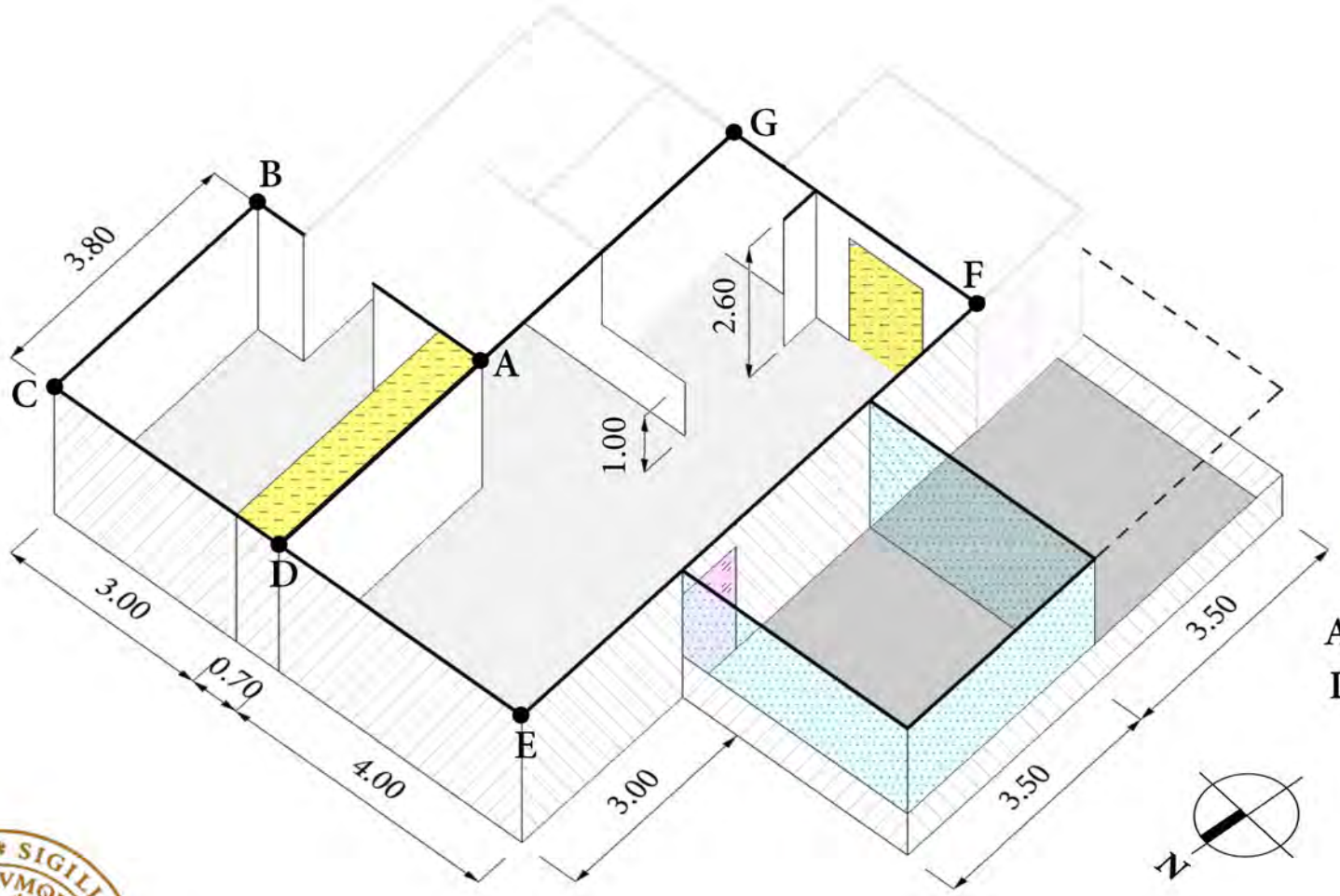
1. NW APARTMENT
Area: 68 m²



Fenestration study in:

Living room
Bedroom

METHOD - Rooms & Fenestration zones



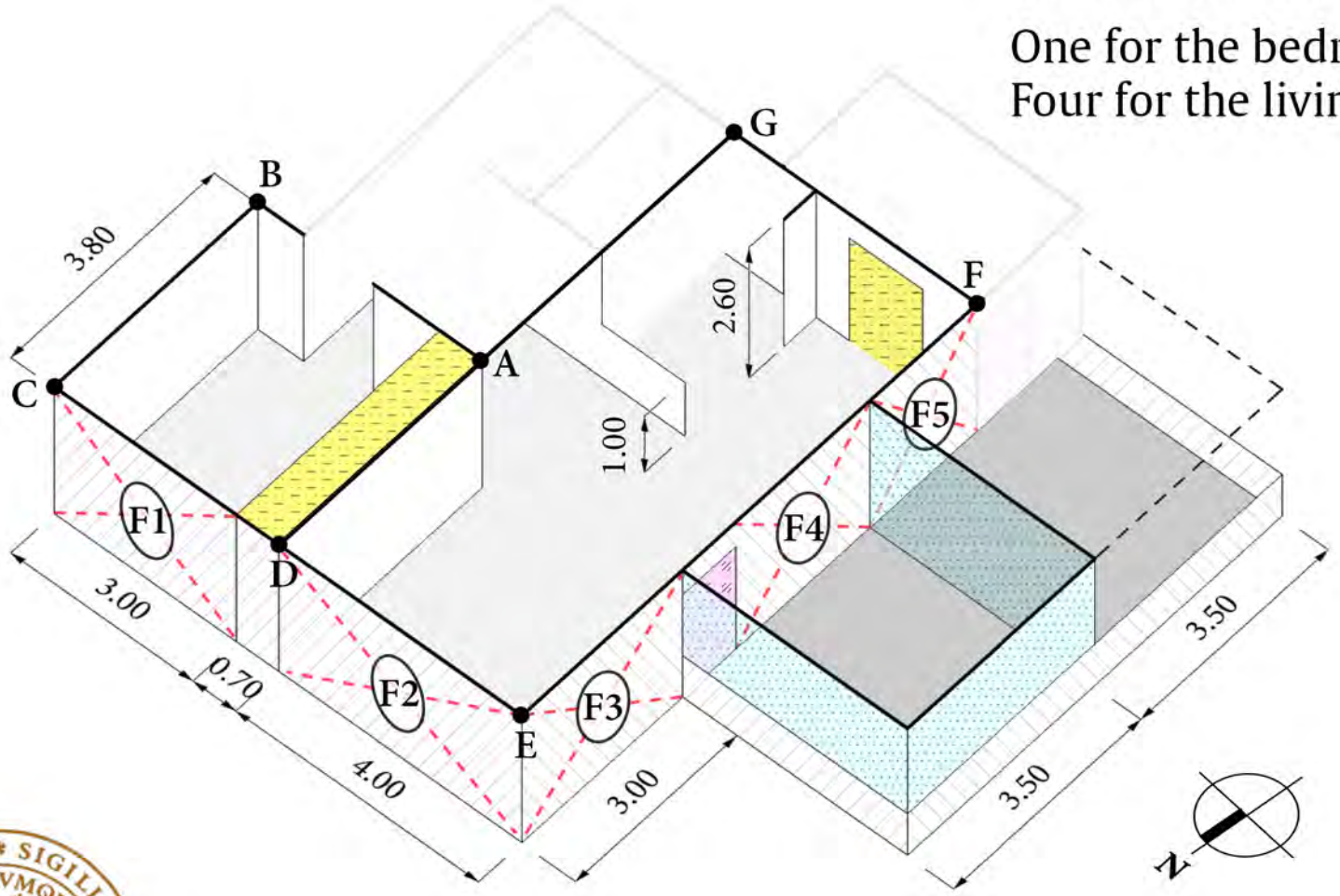
- Walls (interior)
- Walls (exterior)
- Floor
- Balcony floor
- IGU (Glazed door)
- Clear glass
- Furniture

ABCD Bedroom perigram
DEFG Living room perigram

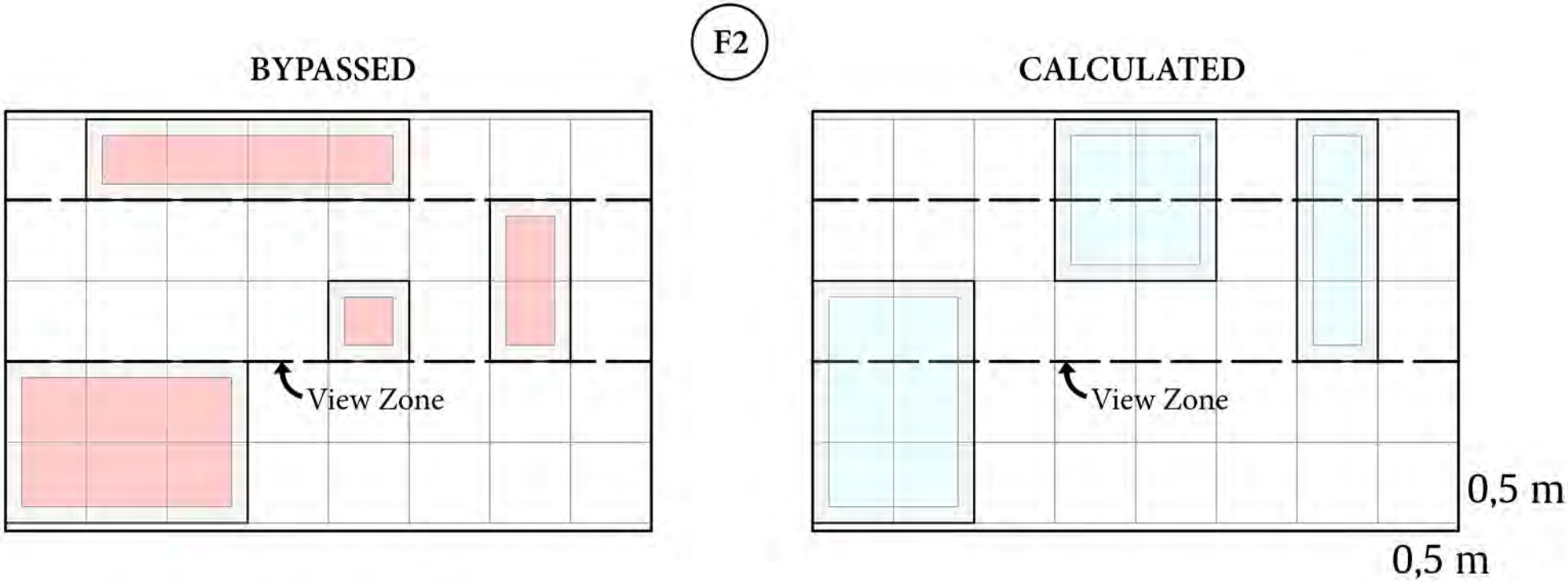
METHOD - Rooms & Fenestration zones

Fenestration zones:

One for the bedroom (F1)
Four for the living room (F2, F3, F4 & F5)



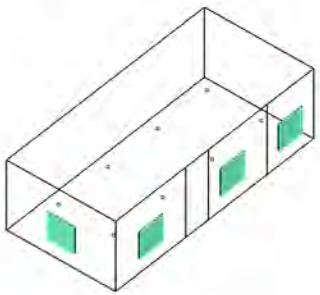
METHOD - Rules and boundaries of fenestration

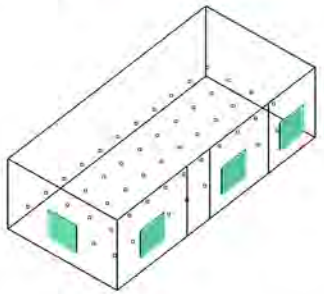


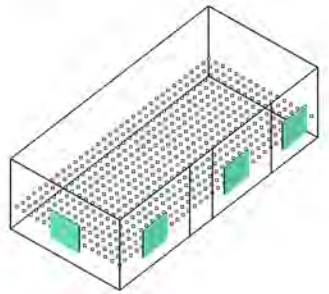
A window is calculated if:

1. It is larger than 0,5 · 0,5 m² or 0,5 · 1,0 m²
2. It is a convex polygon
3. It belongs (at least partly) in the *View Zone*

RADIANCE: Accuracy ➡ Time (Grid spacing, ambient bounces)







Comparison of "*Reference case*" with different grid setups

Tref =22 min	Volumetric difference ΔVol and simulation time															
Ambient Bounces	2				3				4				5			
Position	Low	Medium	High	Time	Low	Medium	High	Time	Low	Medium	High	Time	Low	Medium	High	Time
Grid size / m: 0.50	6	9	14	4.6	4	3	6	11.2	3	3	3	13.0	3	2	2	13.1
0.75	7	7	13	2.2	4	5	6	8.3	4	5	4	10.9	4	5	4	11.3
1.00	6	9	12	1.8	9	10	7	7.3	11	12	5	9.8	9	10	5	10.1
1.25	8	11	10	1.6	11	13	9	6.4	10	14	8	8.9	11	16	7	9.2
1.50	10	20	16	1.1	9	15	15	5.3	9	13	14	7.4	11	13	15	7.9
1.75	10	20	16	1.1	9	15	15	5.3	9	13	14	7.4	11	13	15	7.9
2.00	11	24	13	1.0	10	17	12	5.3	9	16	10	7.4	9	16	10	7.8
2.25	21	18	13	0.6	21	18	13	3.6	21	18	13	5.9	21	18	13	6.3
2.50	21	18	13	0.6	21	18	13	3.6	21	18	13	5.9	21	18	13	6.3

DA deviation units* Time /min

*

FULL REPORT AT:
https://lup.lub.lu.se/student-papers/search/publication/8885759

PROBLEM - Large number of possible fenestration alternatives

Multiple window variables
lead to a vast solution space*

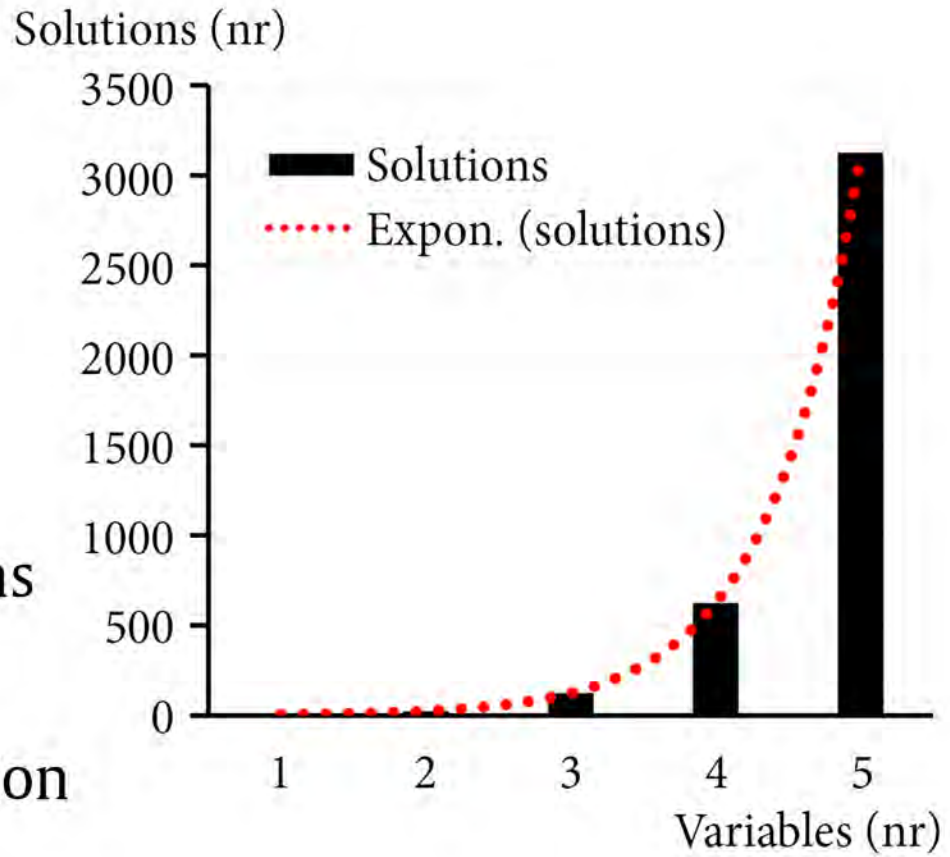
This thesis case: 7,3 million solutions

x

11 minutes per solution

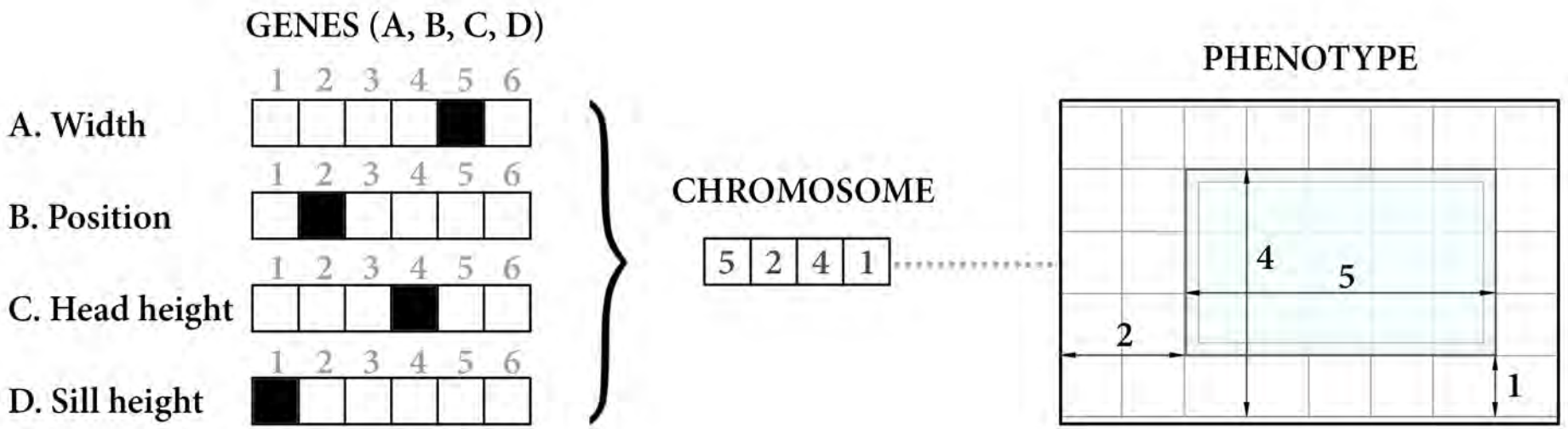
=

153 years of simulation time

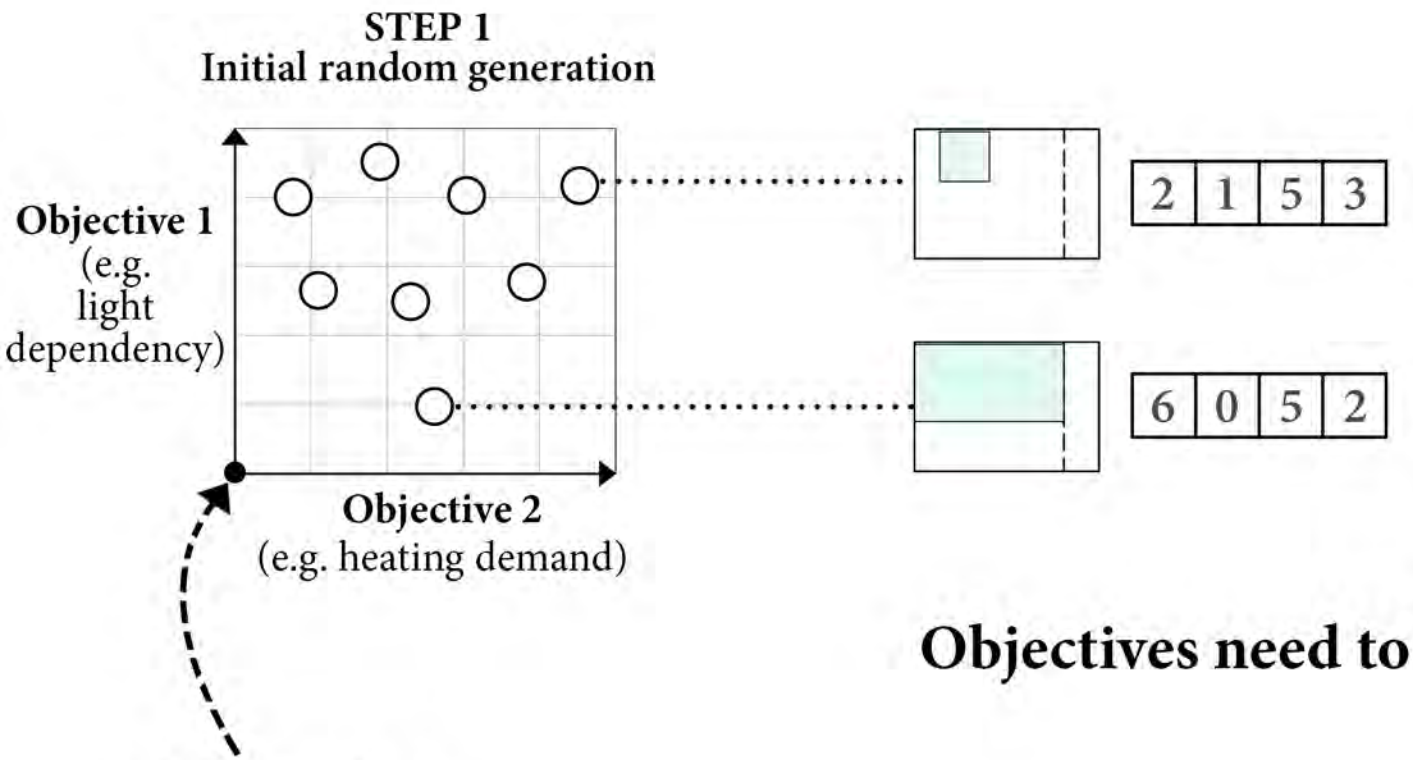


*The total of solutions plotted on a cartesian plane

SOLUTION - Use of Genetic Algorithm



GENETIC ALGORITHM - Exemplified optimization process

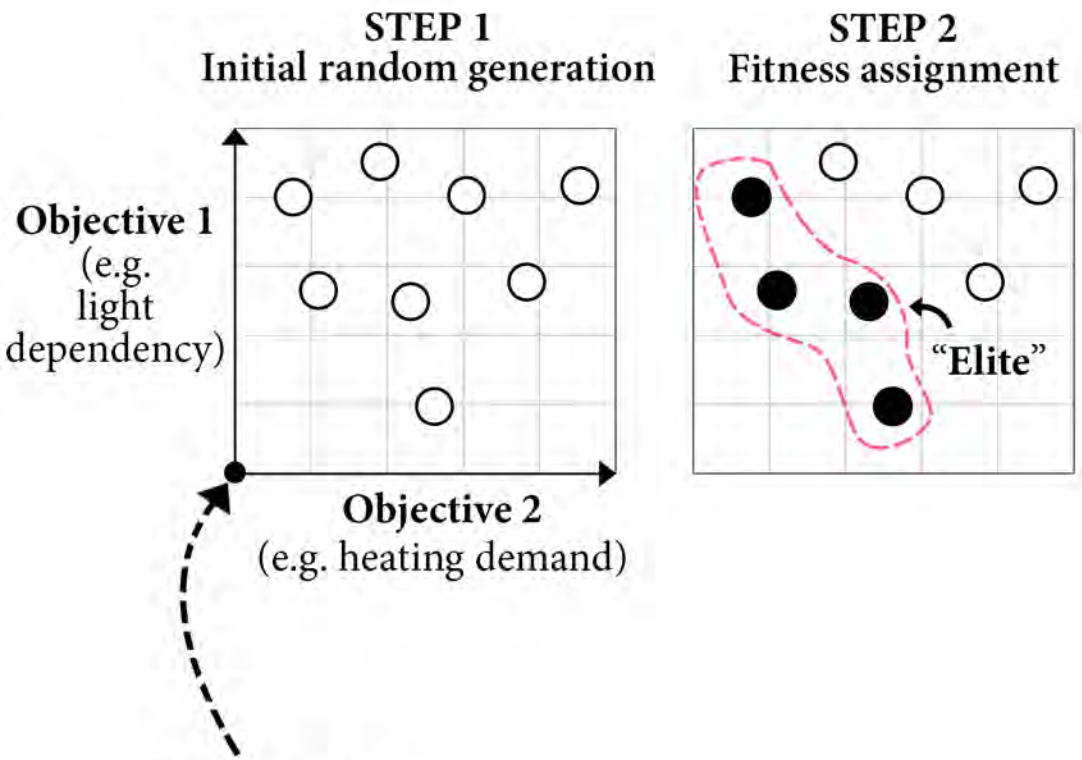


Objectives need to be minimized

Origin point

Solutions should converge towards it

GENETIC ALGORITHM - Exemplified optimization process



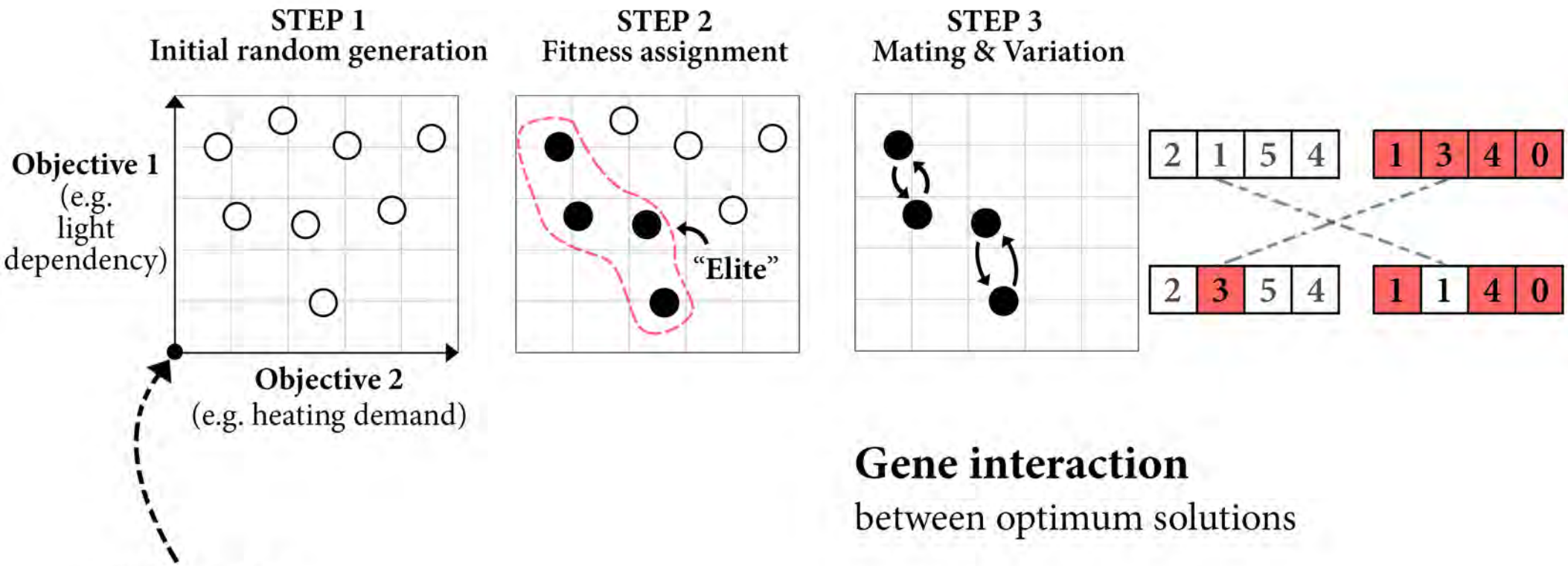
Origin point

Solutions should converge towards it

Solutions are ranked

based on performance to objectives

GENETIC ALGORITHM - Exemplified optimization process



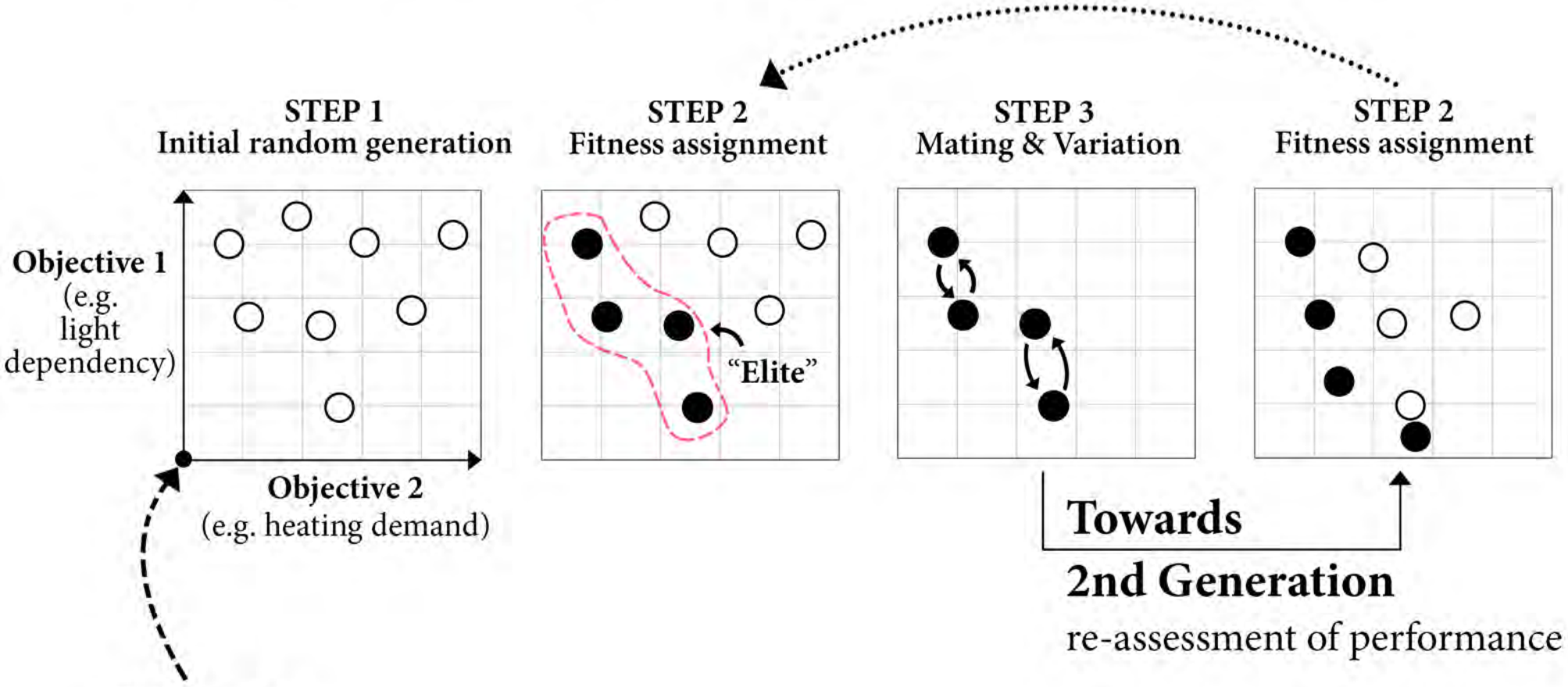
Origin point

Solutions should converge towards it

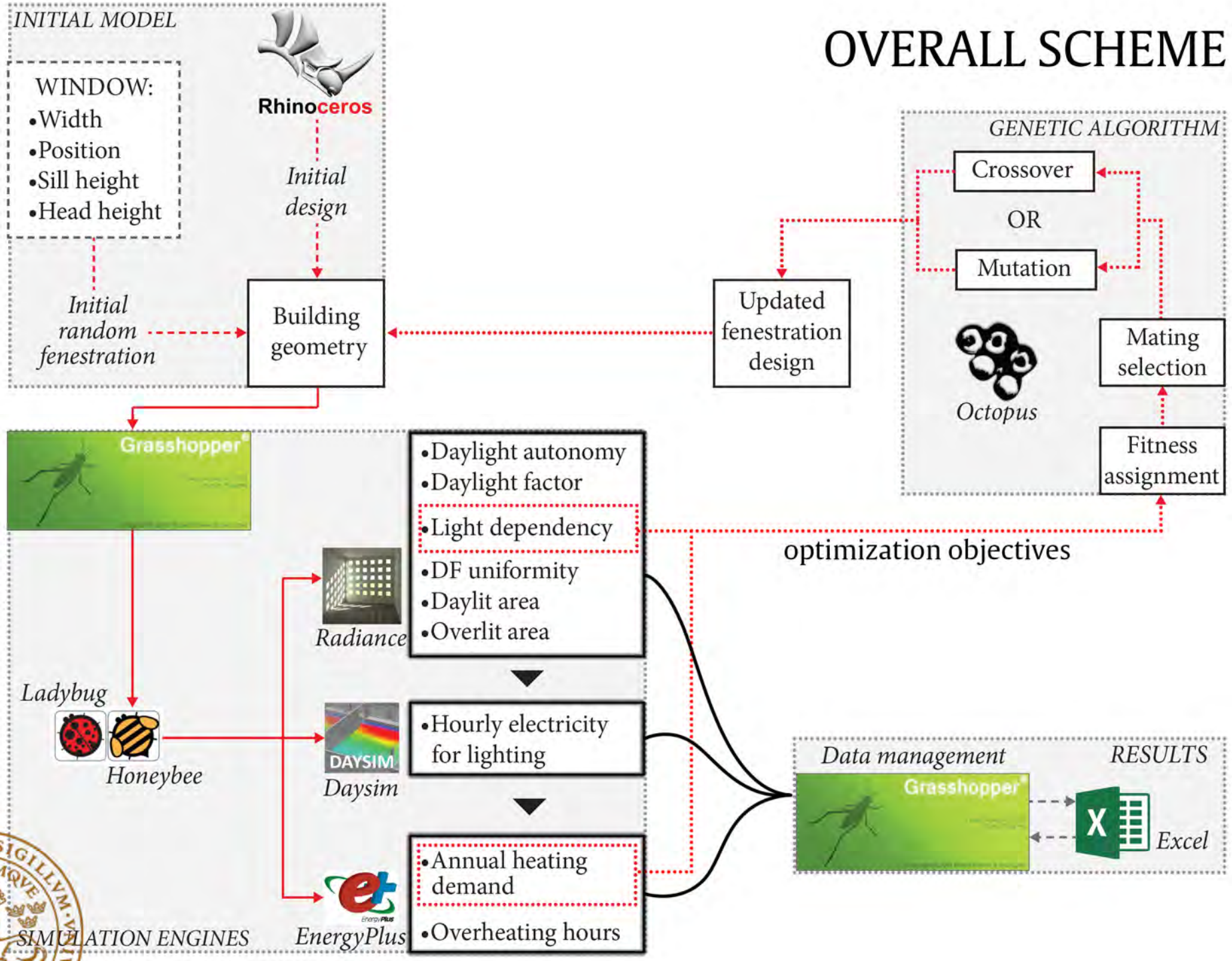
Gene interaction

between optimum solutions

GENETIC ALGORITHM - Exemplified optimization process

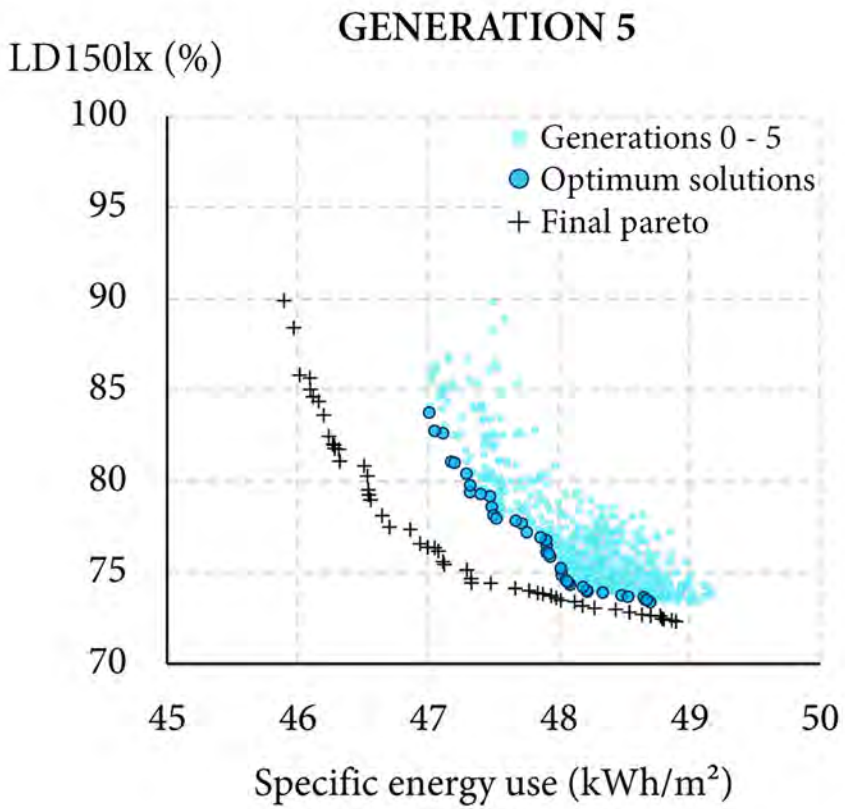


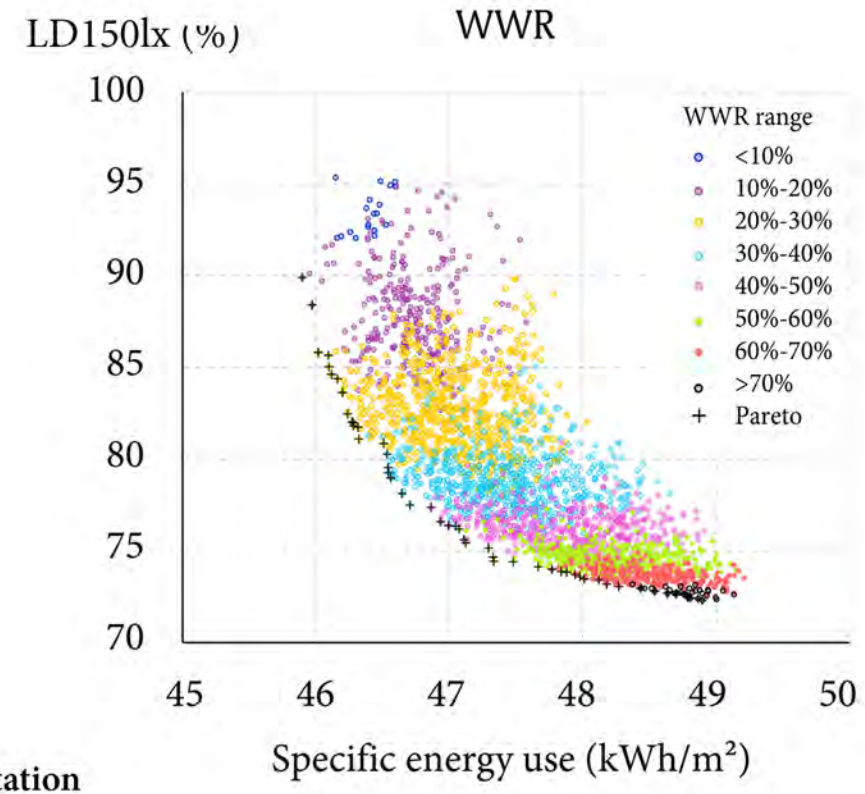
OVERALL SCHEME

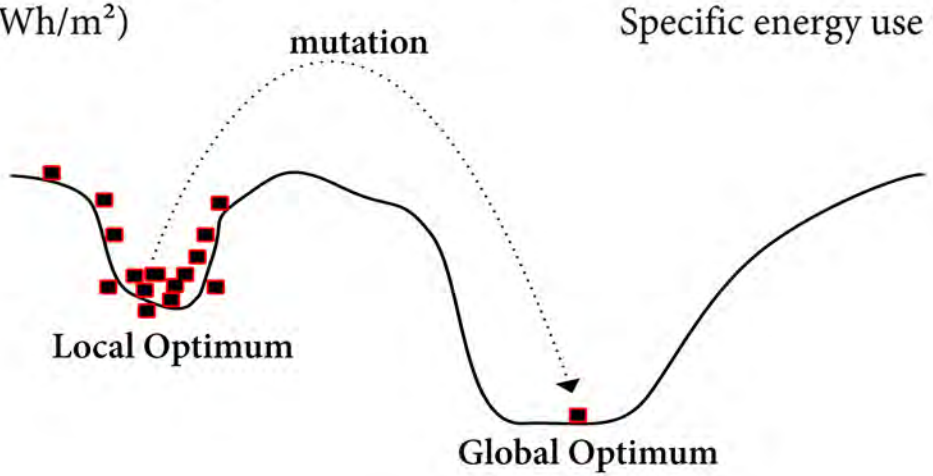


RESULTS - Living room.

Heating/daylighting Optimization







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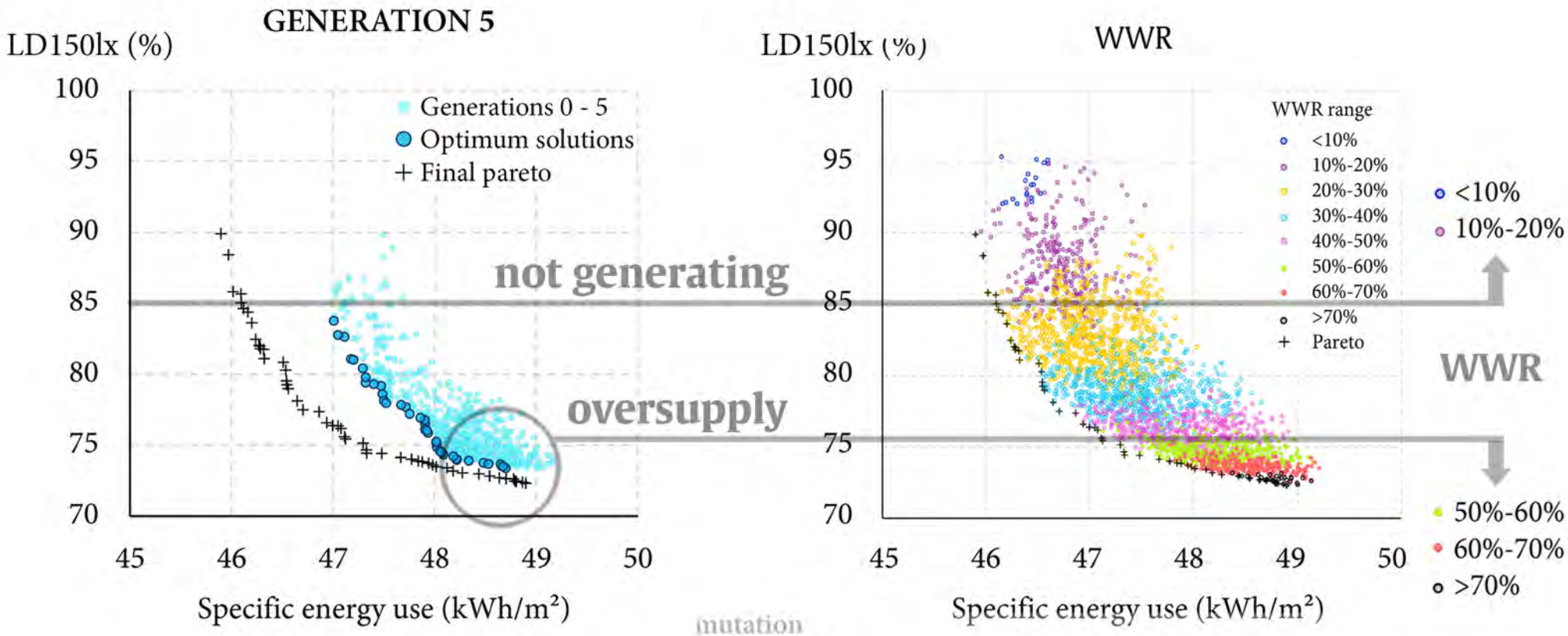
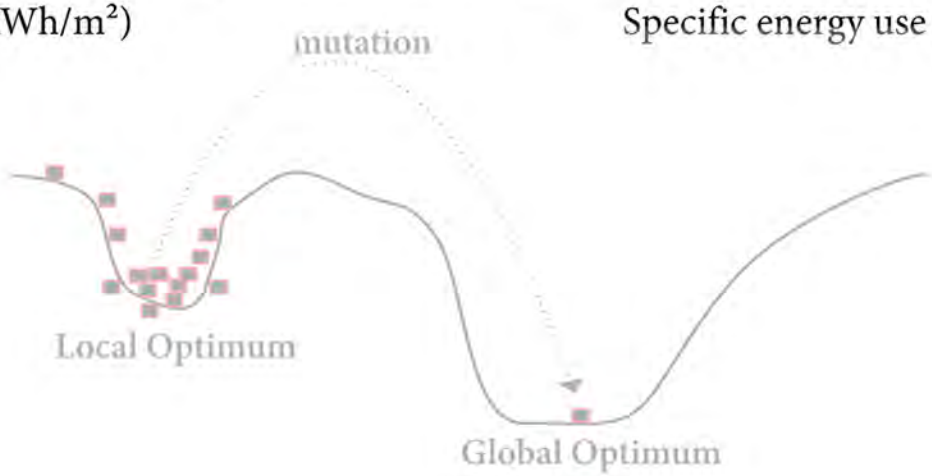
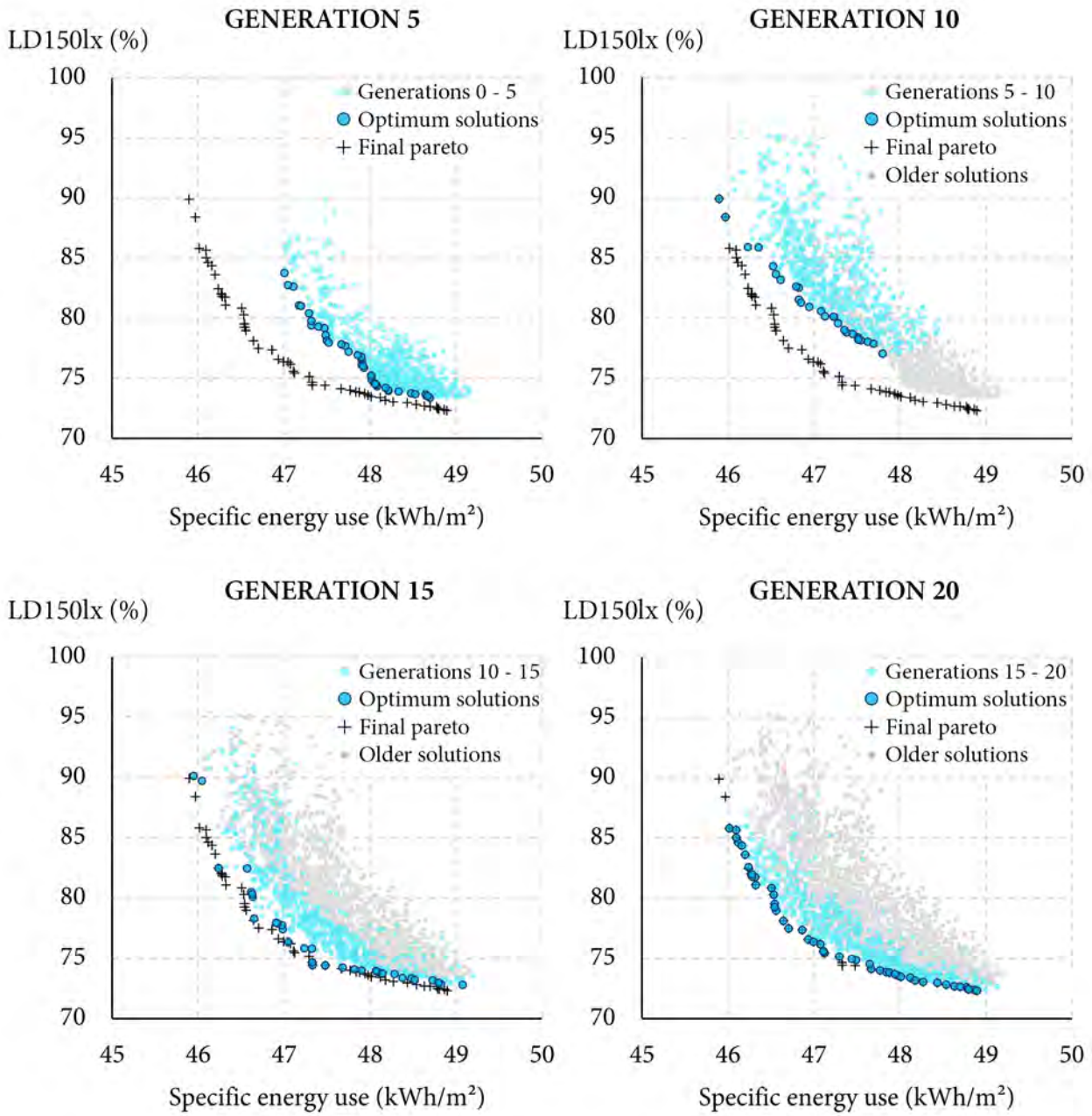




RESULTS - Living room. Heating/daylighting Optimization



RESULTS - Living room.

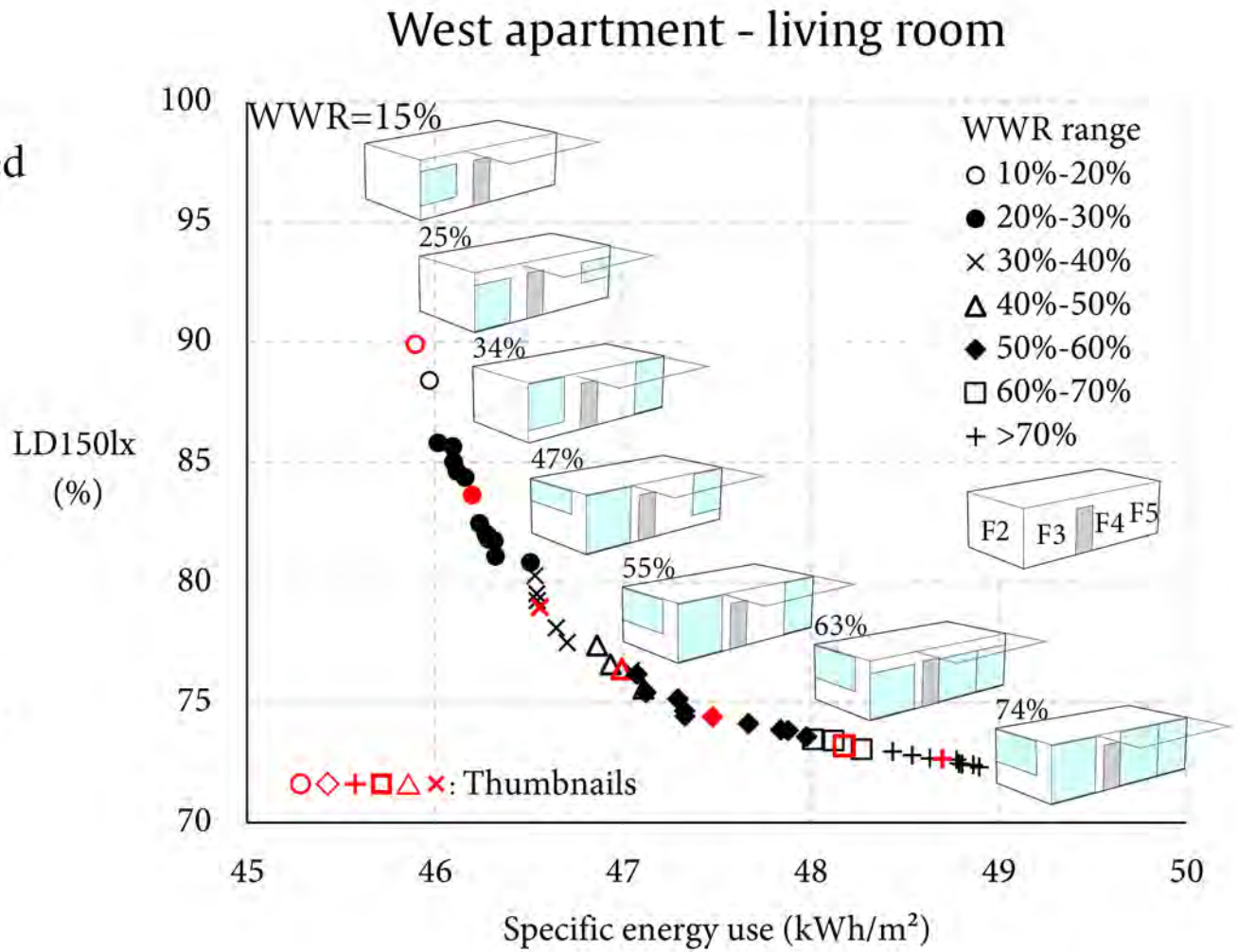
Heating/daylighting Optimization

For WWR < 20 %, F3 is populated

Then F5 is also utilized

For WWR > 40 % the Northern fenestration zone must be used, three windows in total

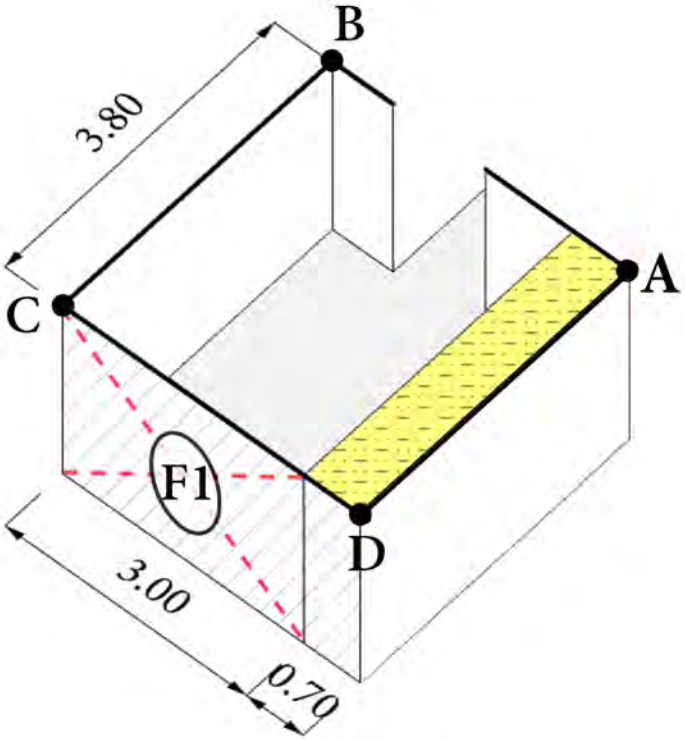
For WWR > 60 % four windows are necessary,
no daylight improvement



RESULTS - Bedroom.

Heating/daylighting Optimization

WWR	ORIENTATION NORTH	EAST	WEST	SOUTH
10 %-20 %	WWR=10%, 10%, 10%, 16%, 16%			
20 %-30 %	23%, 23%			
30 %-40 %	32%, 32%, 39%, 39%	39%		
40 %-50 %	47%	42%, 42%, 47%	42%, 47%	
50 %-60 %		52%	52%, 52%	
60 %-70 %	62%	62%		
>70 %			78%	78%



Same for the bedroom

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THANK YOU

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Supervisor: Marie-Claude Dubois, *Energy and Building Design, LTH*
Examiner: Maria Wall, *Energy and Building Design, LTH*

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