04.05.2023 | RESEARCH CAFÉ

ODS 7: LA NOVA ERA D'EDIFICIS EFICIENTS I SOSTENIBLES
L'ENGINYERIA DE L'ENERGIA I L'ARQUITECTURA CREANT SINERGIES

MULTI-OBJECTIVE OPTIMIZATION OF RESIDENTIAL MULTIFAMILY BUILDINGS TO MINIMIZE COOLING AND HEATING SIMULTANEOUSLY

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UFRGS
UNIVERSIDADE FEDERAL DO RIO GRANDE DO SUL

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PROGRAMA DE PÓS GRADUAÇÃO
EM ENGENHARIA CIVIL
CONSTRUÇÃO E INFRAESTRUTURA

LIfE
SUSTAINABILITY

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ETSAB
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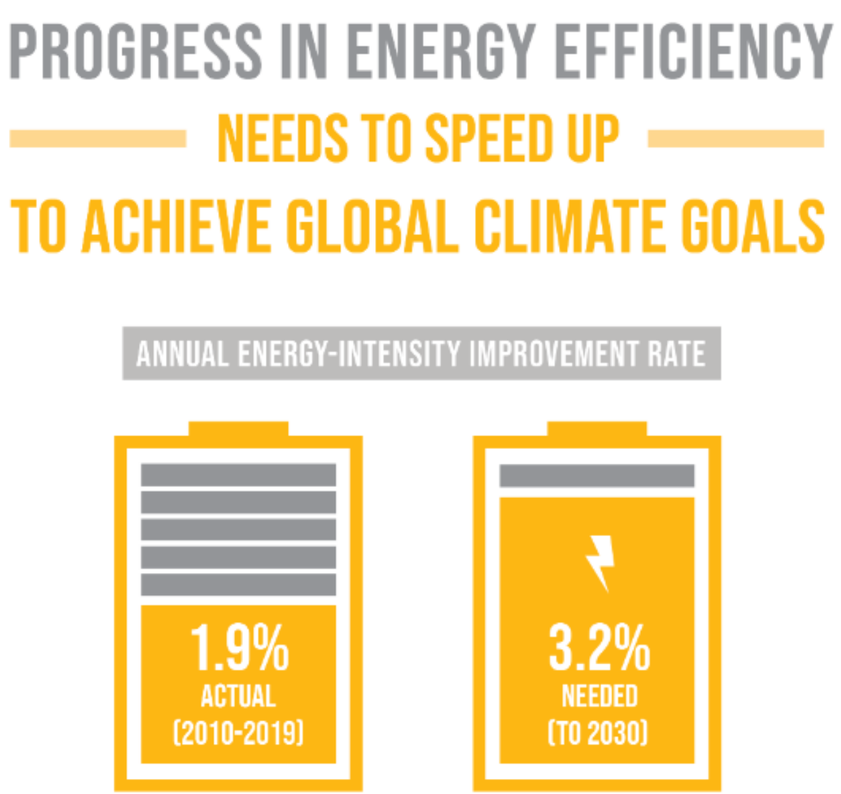
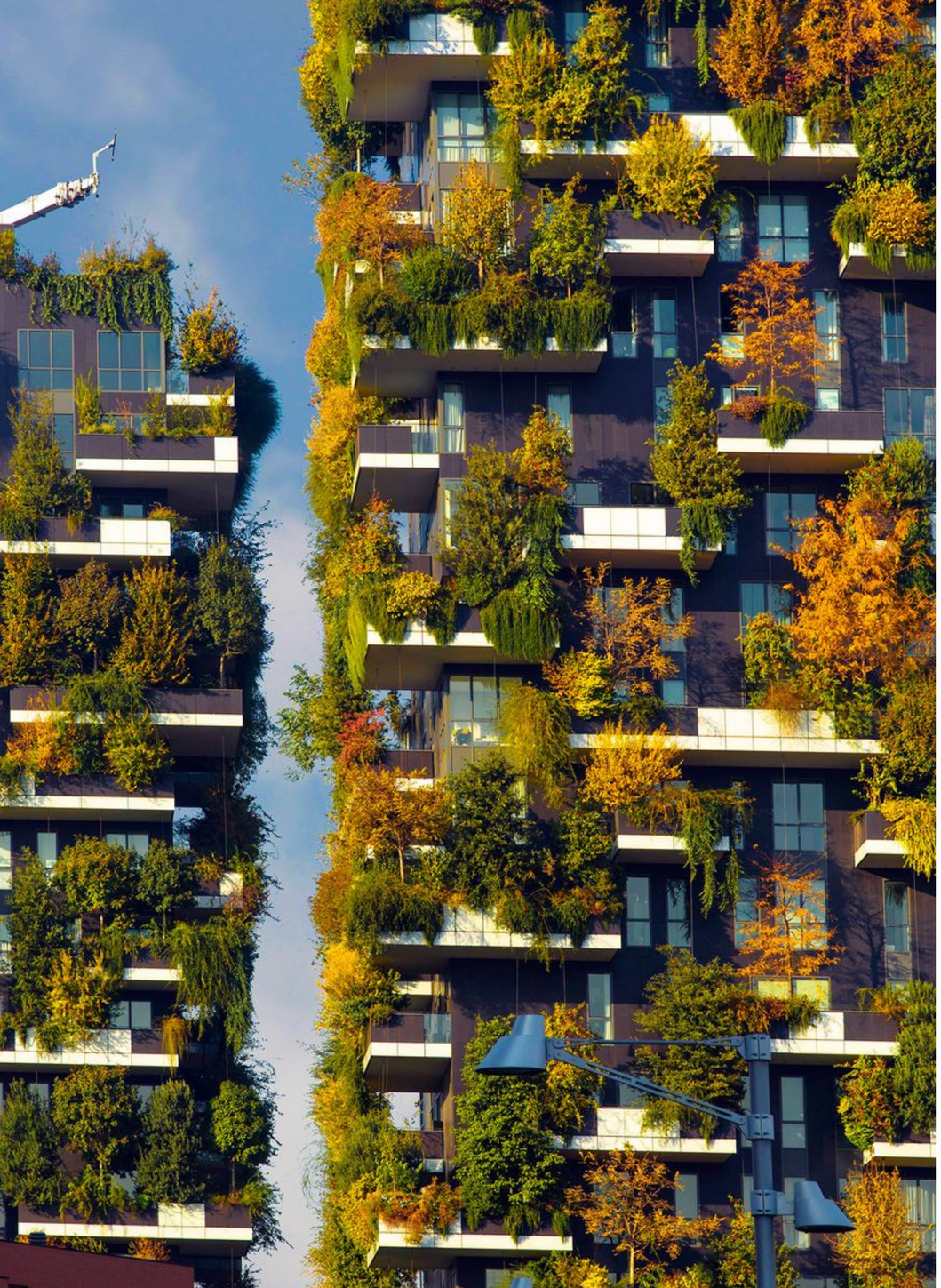
- Introduction
- Research problem
- Method
- NSGA-II
- Multi-objective
- Optimizations
- Conclusions

ENSURE ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL



THE SUSTAINABLE DEVELOPMENT GOALS REPORT 2022: UNSTATS.UN.ORG/SDGS/REPORT/2022/



__INTRODUCTION

Thesis novelty:

- Analysis of two scenarios (isolated and condominium) to compare how the shadows of the surroundings can impact the demand of the building.
- Improvement in the envelope utilized passive strategies.
- The energy demand for apartment positioning enhances the discussion about energy vulnerability between neighbors.
- Implementation and evaluation of the presented multi-objective optimization framework in case study buildings based on real models replicated worldwide.
- All open-access software were used for this experiment.

CHALLENGES TO BUILT ENVIRONMENT

RESEARCH
PROBLEM

GLOBAL

Anthropogenic impacts:
Human activity
Global warming
Desertification
Non-renewable resources

BUILDINGS

Built environment impacts:
Gas emissions
Ambiental impacts
Urban heat islands
Increase in energy consumption

ECONOMY

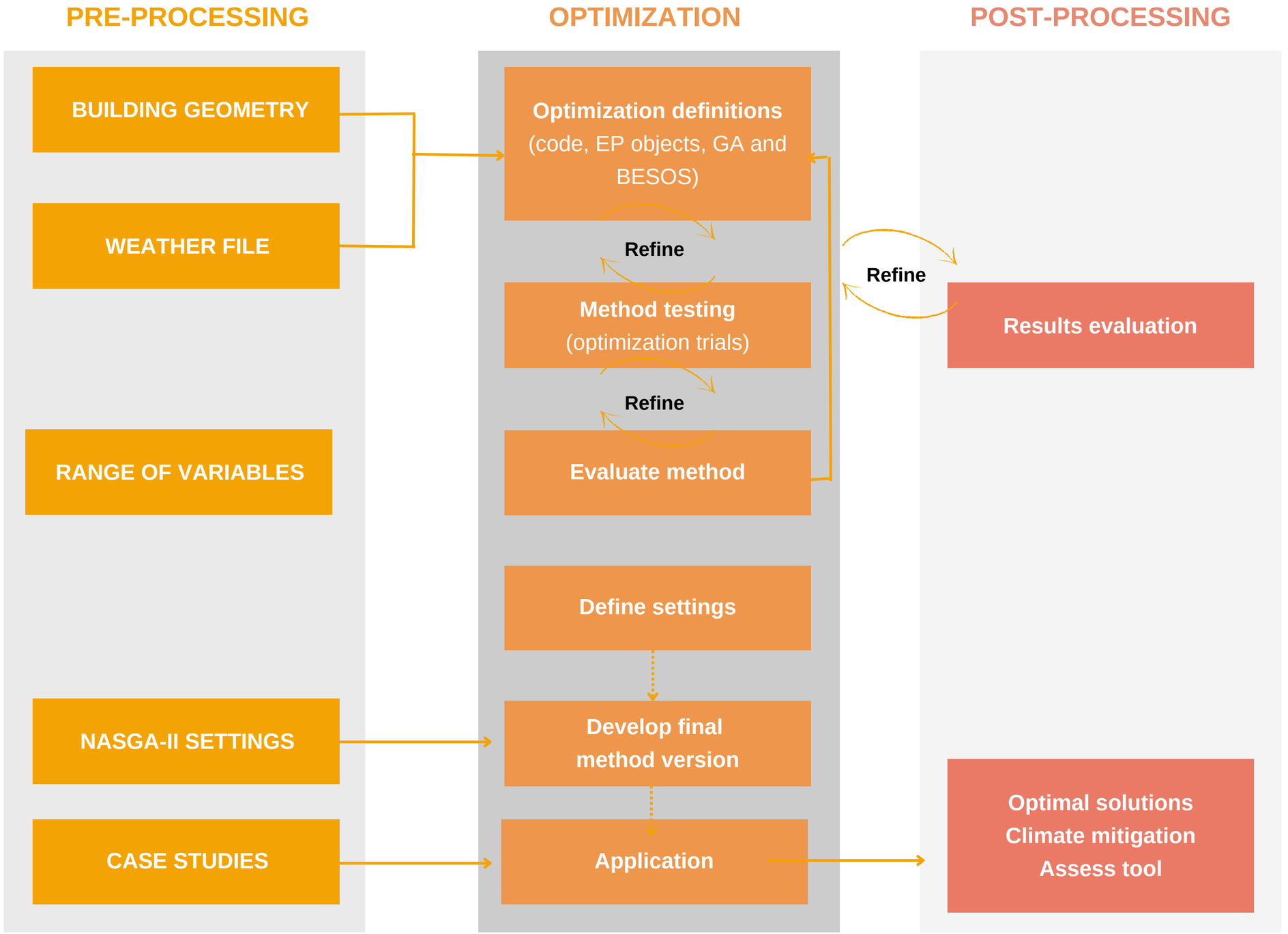
Economical impacts:
Increase purchase levels
Rising prices
Low performance buildings
Lack of manpower

SOCIETY

Population growth impacts:
Urban pressure
More floor area
Social inequalties
Energy poverty

Santamouris and Vasilakopoulou (2021),
UN (2019; 2022), and IPCC (2022)

METHOD

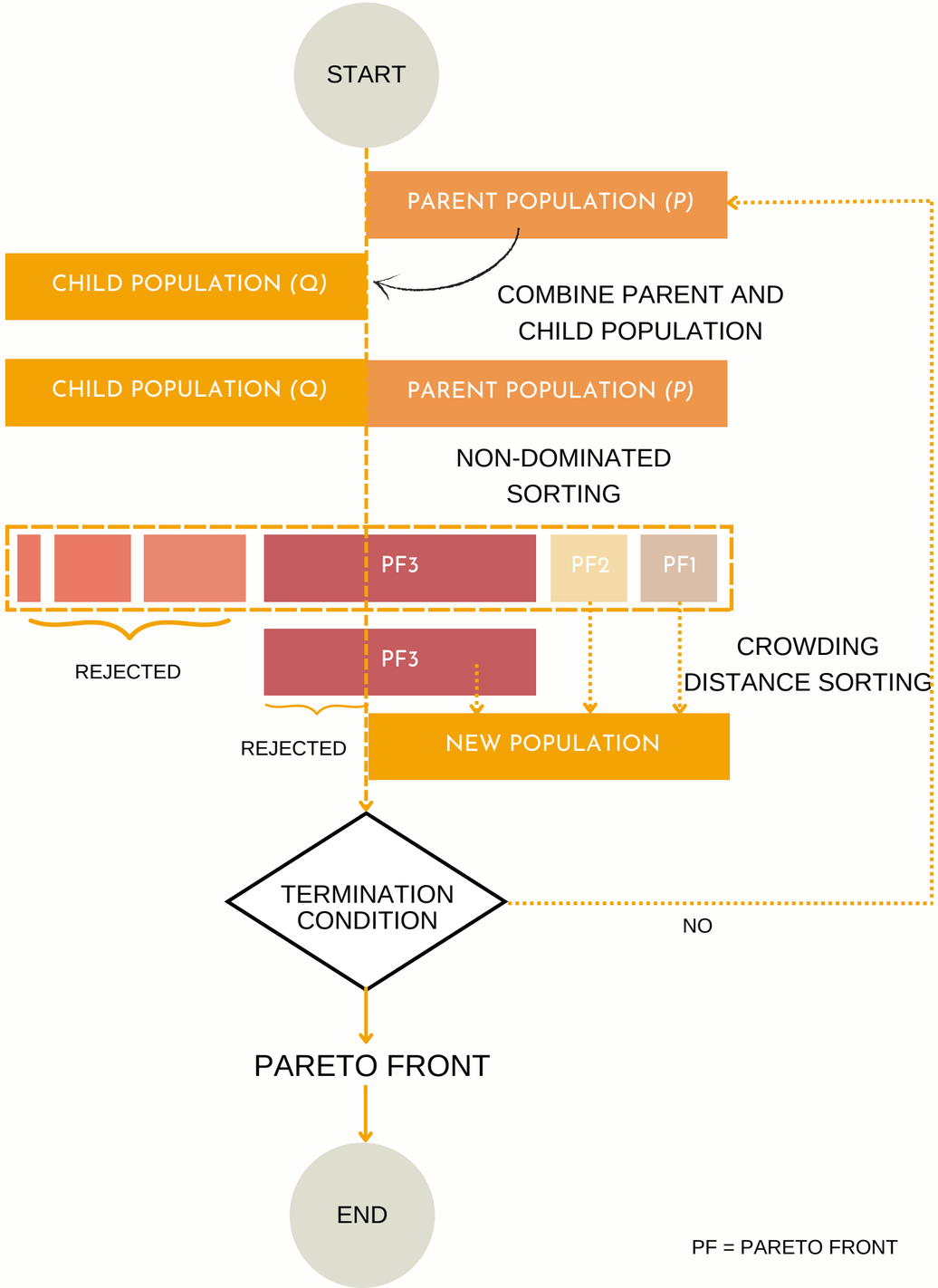

PRE-PROCESSING
OPTIMIZATION
POST-PROCESSING
BUILDING GEOMETRY
WEATHER FILE
RANGE OF VARIABLES
NASGA-II SETTINGS
CASE STUDIES
Optimization definitions
(code, EP objects, GA and BESOS)
Refine
Method testing
(optimization trials)
Refine
Evaluate method
Refine
Results evaluation
Define settings
Develop final method version
Application
Optimal solutions
Climate mitigation
Assess tool

METHOD

ACTION	SOFTWARE	DEFINITIONS
model	SketchUp +	building: geometry thermal zones
envelope configuration, building use, occupation, equipment's and lighting TERMOENERGETIC SIMULATIONS	EnergyPlus	Construction Properties [NBR 15220/15575] Occupation schedule Lighting schedule Equipment's load Natural Ventilation Ground Metabolic rate [INI-R] Weather file [BZ2]
Simulation, optimization and outcome results	python + jupyter	Minimize cooling demand (Dc) Minimize heating demand (Dh)

ALL SOFTWARES ARE OPEN-ACESS

NSGA-II



Non-Dominated Sorting Genetic Algorithm II

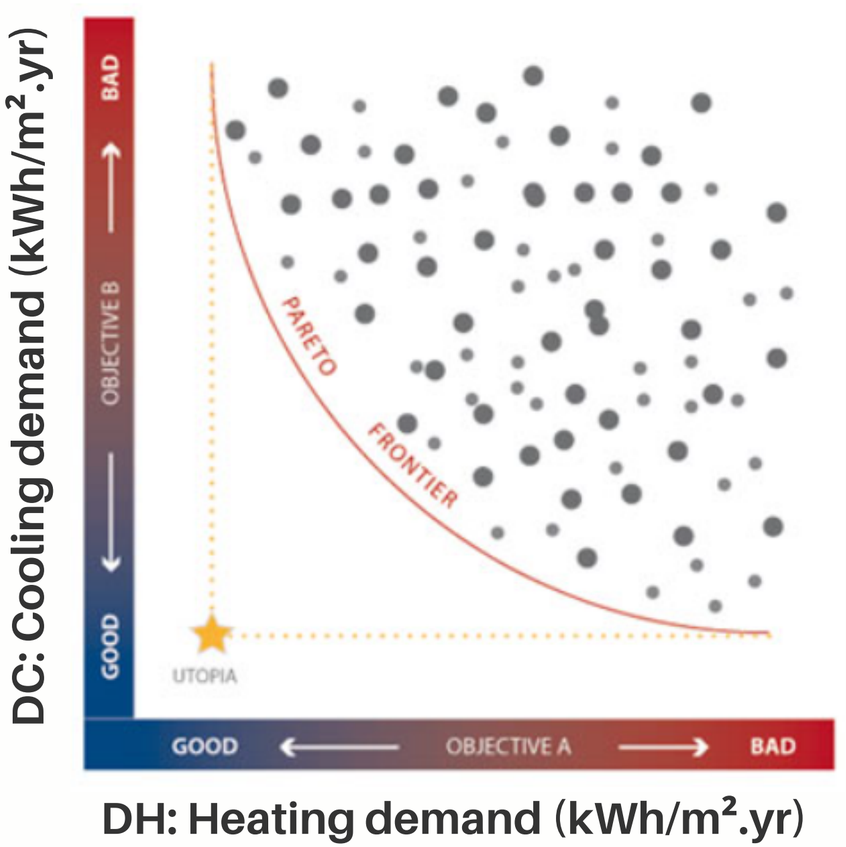
Proposed by Deb et al. (2002).

Best suited for solving multi-objective optimization problems of an architectural and engineering nature.

Uses crowding distance, which means that it seeks convergence of the fittest genes after the first random generation

Manni and Nicolini, 2022; Hashempour et al., 2020; Costa-Carrapiço et al., 2020; Attia, 2013; Fortin, 2013 and Deb et al., 2002

MULTI-OBJECTIVE



Multi-objective analysis is a decision-making process that considers multiple objectives or criteria to find the best possible solution.

The Pareto Front is a graphical representation that shows the set of optimal solutions in a multi-objective analysis, where no other solution can improve one objective without sacrificing another.

In other words, it represents the trade-offs between different objectives and helps decision-makers identify the best solution for their needs.

Manni and Nicolini, 2022; Hashempour et al., 2020; Costa-Carrapiço et al., 2020

__ OPTIMIZATIONS

OPTIMIZATIONS

CLIMATIC CONTEXT: Cfa

Location: Passo Fundo, BRA

Longitude: -52.41

Latitude: -28.26

Elevation above sea level: 684.0 m

Köppen–Geiger climate zone: Cfa. Humid subtropical, no dry season.

Average yearly temperature: 17.5 °C

Hottest yearly temperature (99%): 29.4 °C

Coldest yearly temperature (1%): 5.1 °C

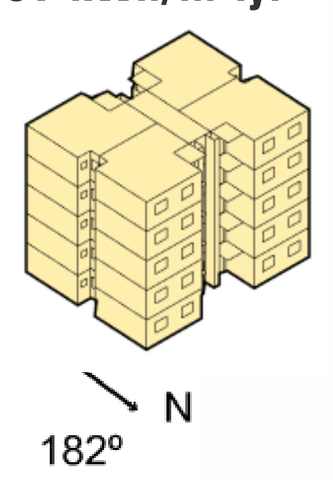
Annual cumulative horizontal solar radiation: 1668.56 Wh/m^2

Percentage of diffuse horizontal solar radiation: 44.4 %

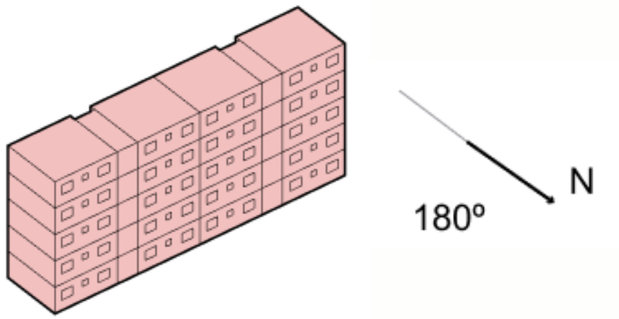
PHASE I: ISOLATED SCENARIO

Optimal solar orientation

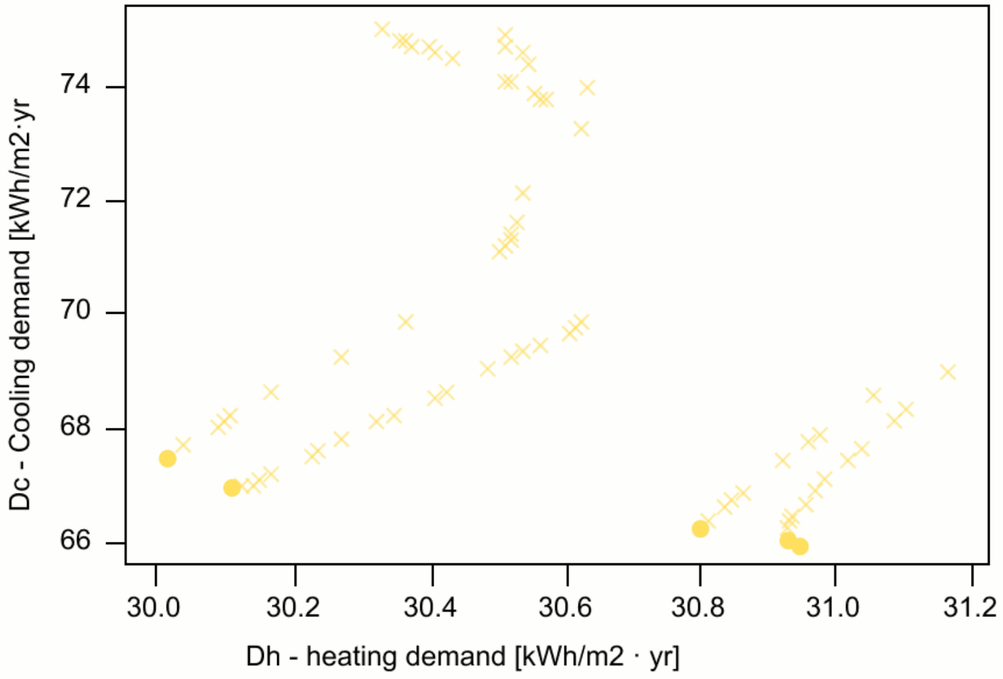
97 kWh/m².yr



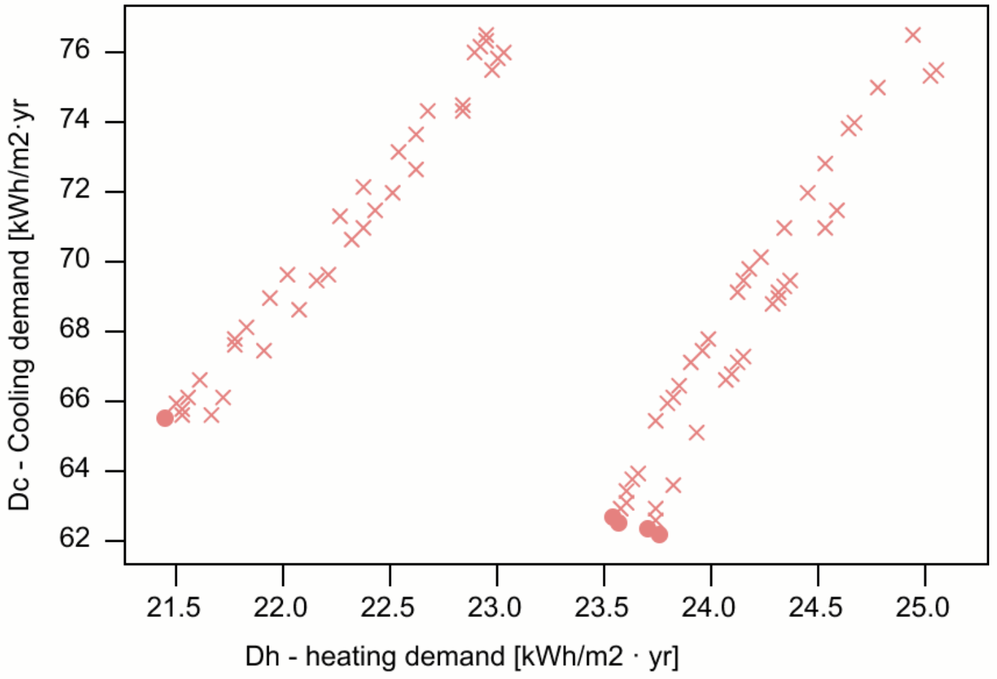
86 kWh/m².yr



"H" BUILDING



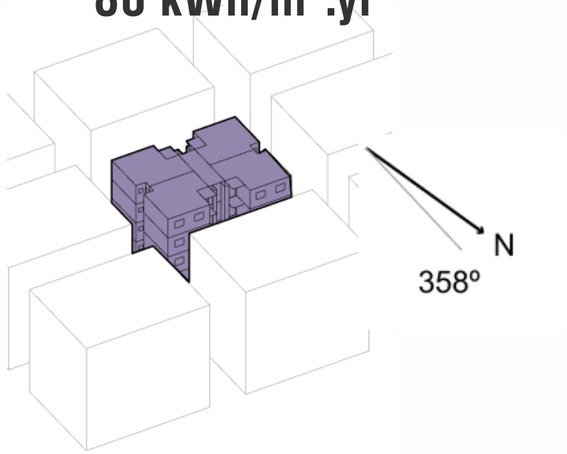
LINEAR BUILDING



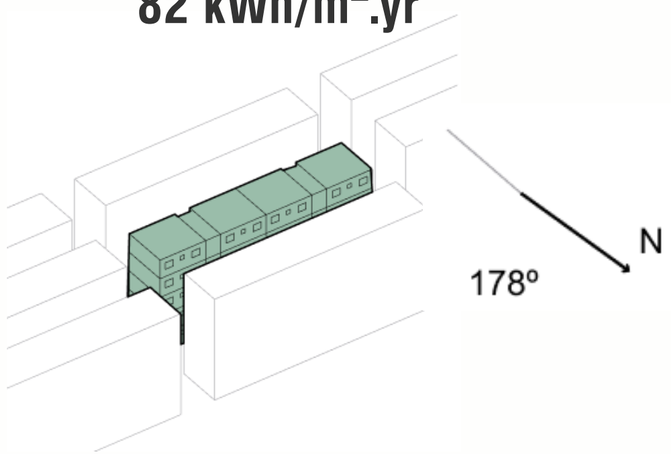
PHASE II: CONDOMINIUM SCENARIO

Optimal solar orientation with shadows

86 kWh/m².yr



82 kWh/m².yr



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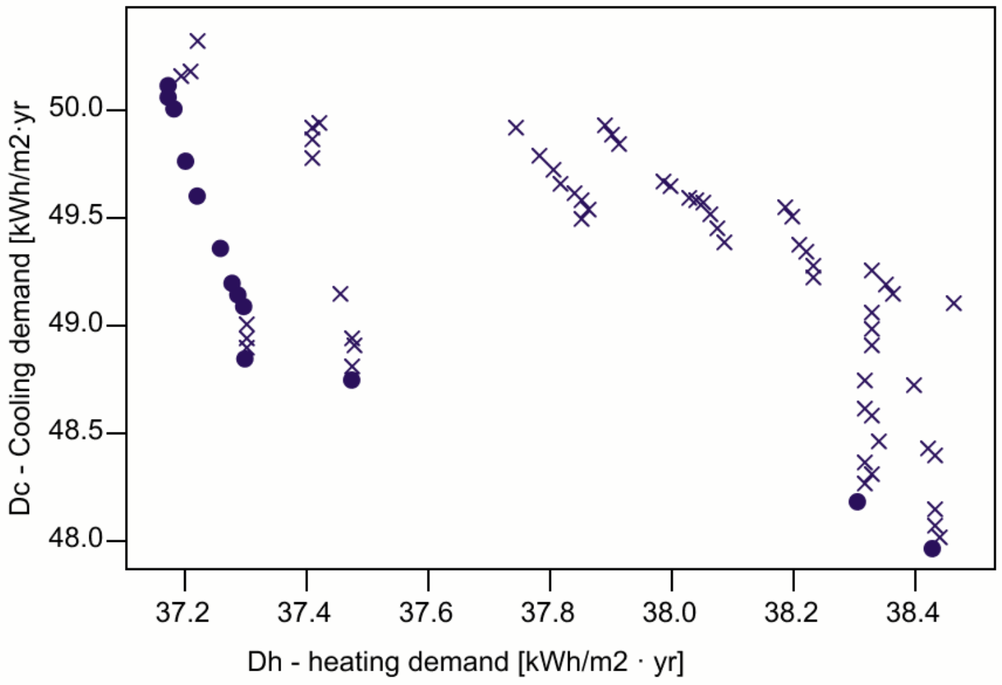
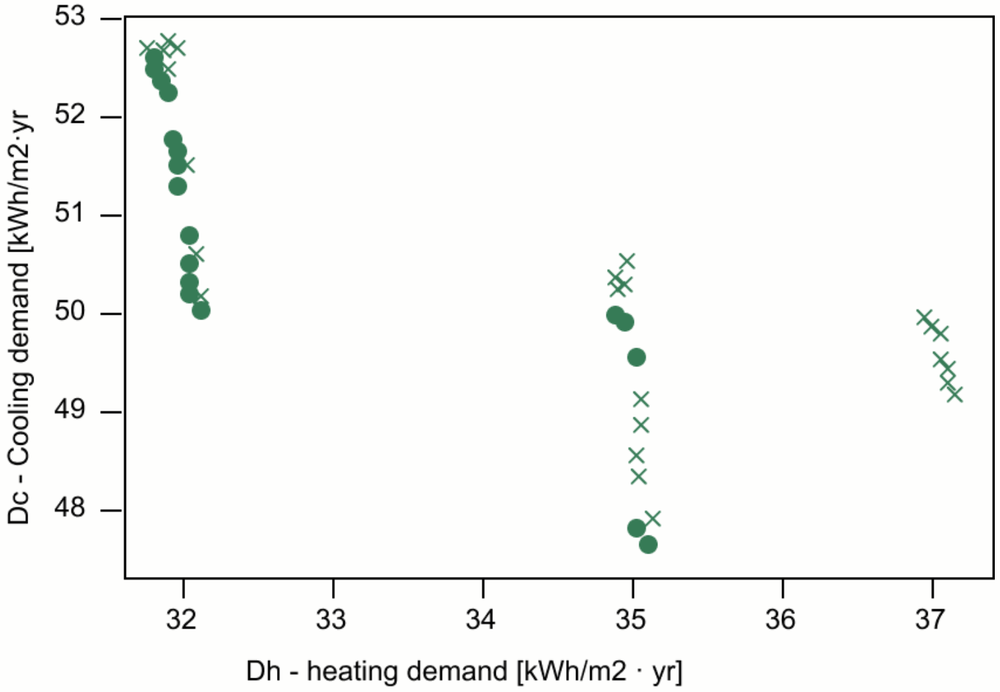


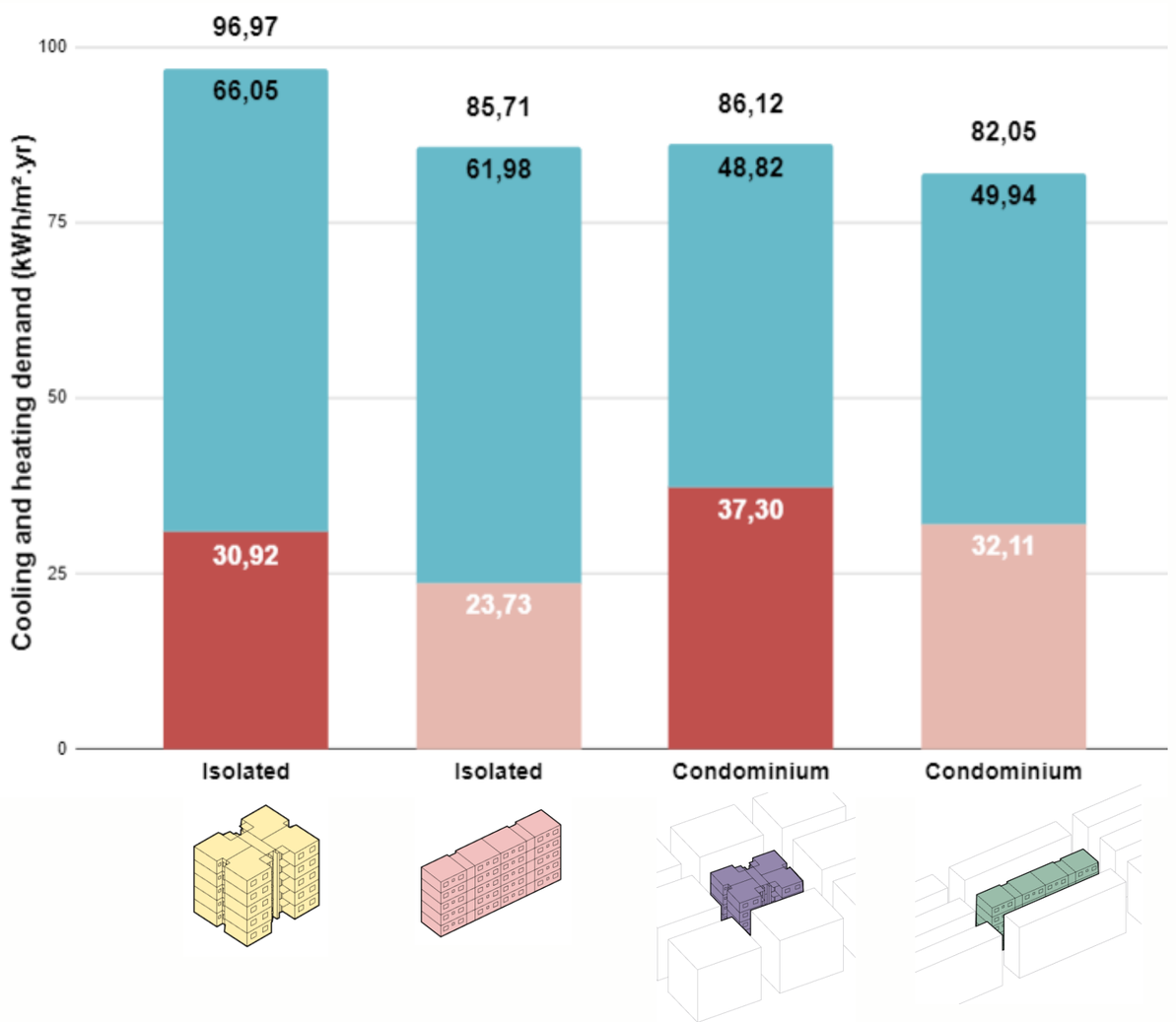
LINEAR BUILDING



PHASE I AND II COMPARISON

Optimal solar orientation

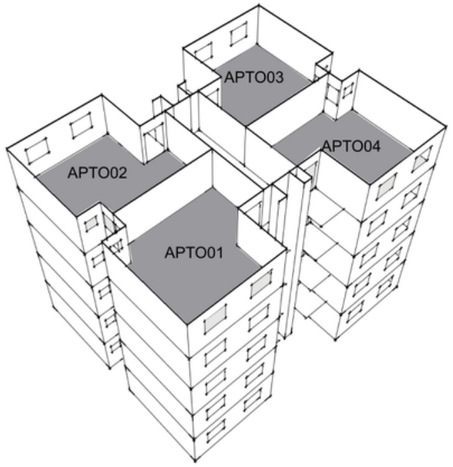
Optimal solution: cooling and heating demands (kWh/m^2.yr)

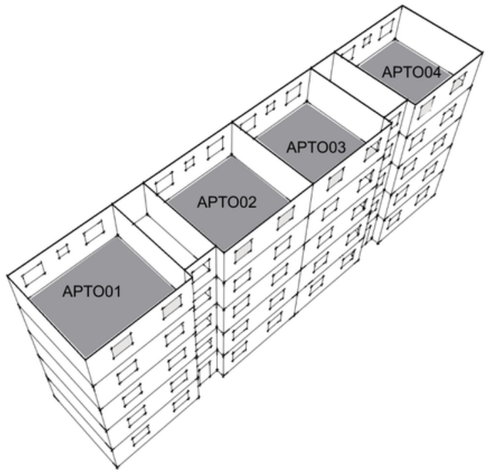


PHASE III: ENVELOPE

Window-to-wall-ratio (WWR): Reference building, 15%, 20% and 25%.

Optimization variables: Insulation thickness wall North, South, East and West. Insulation thickness roof. Solar absorptance walls and roof. Glazing thickness. Setpoint ventilation.

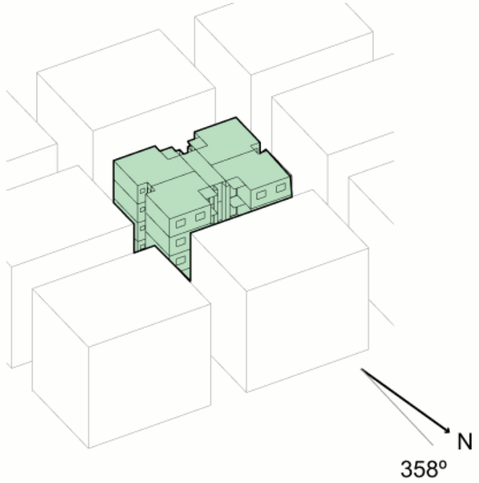




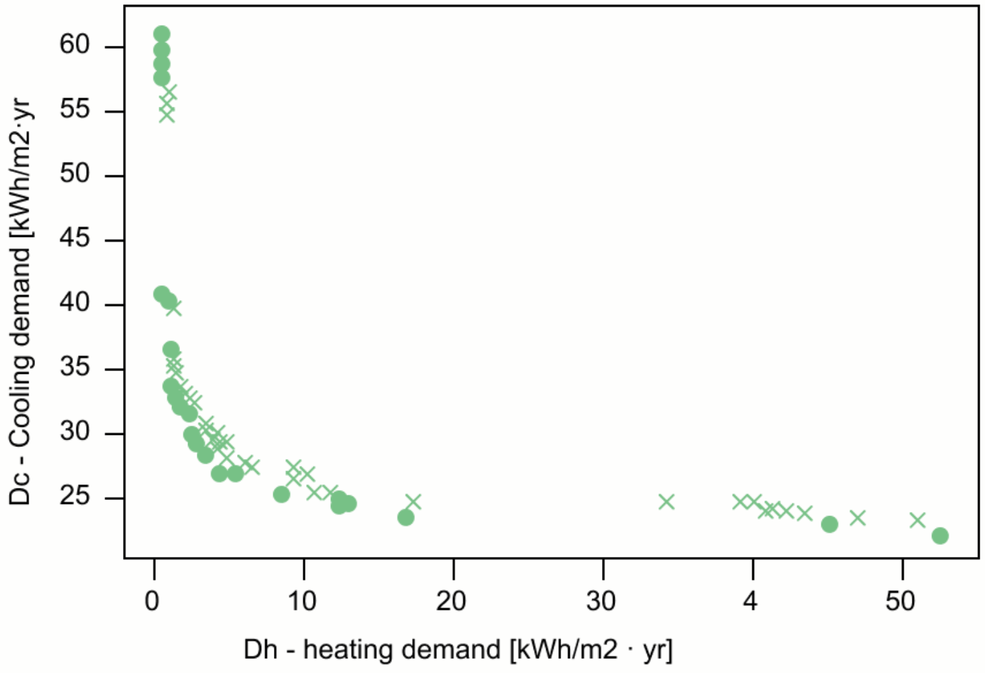
PHASE III: ENVELOPE

Window-to-wall-ratio (WWR): 20%.

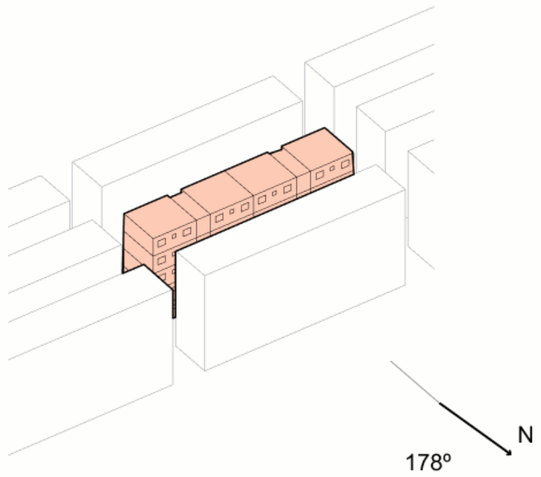
31.7 kWh/m².yr



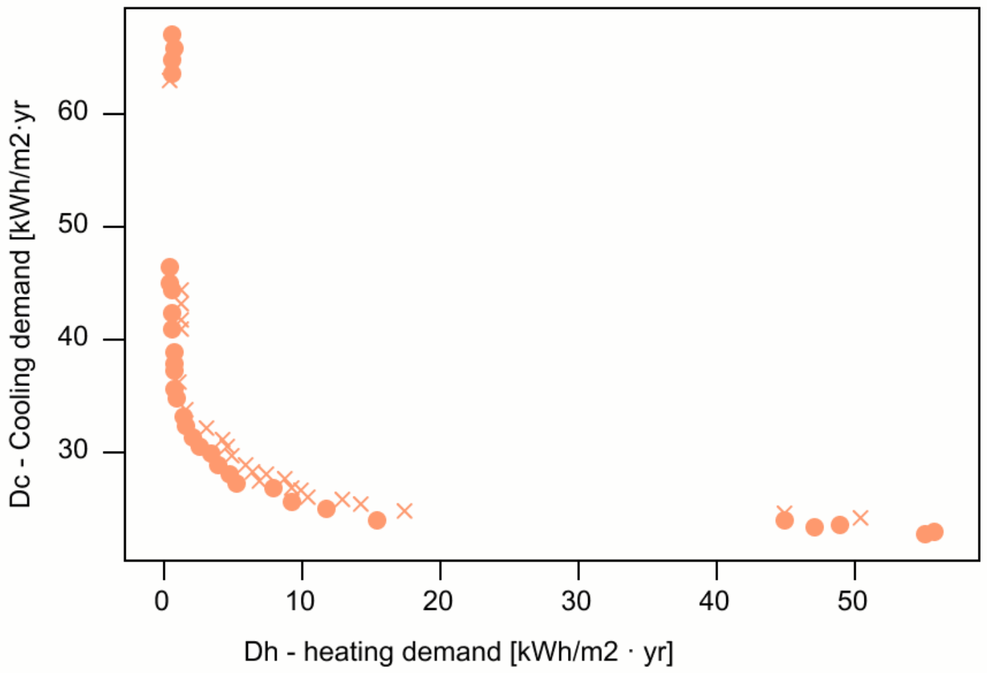
“H” BUILDING



32.4 kWh/m².yr



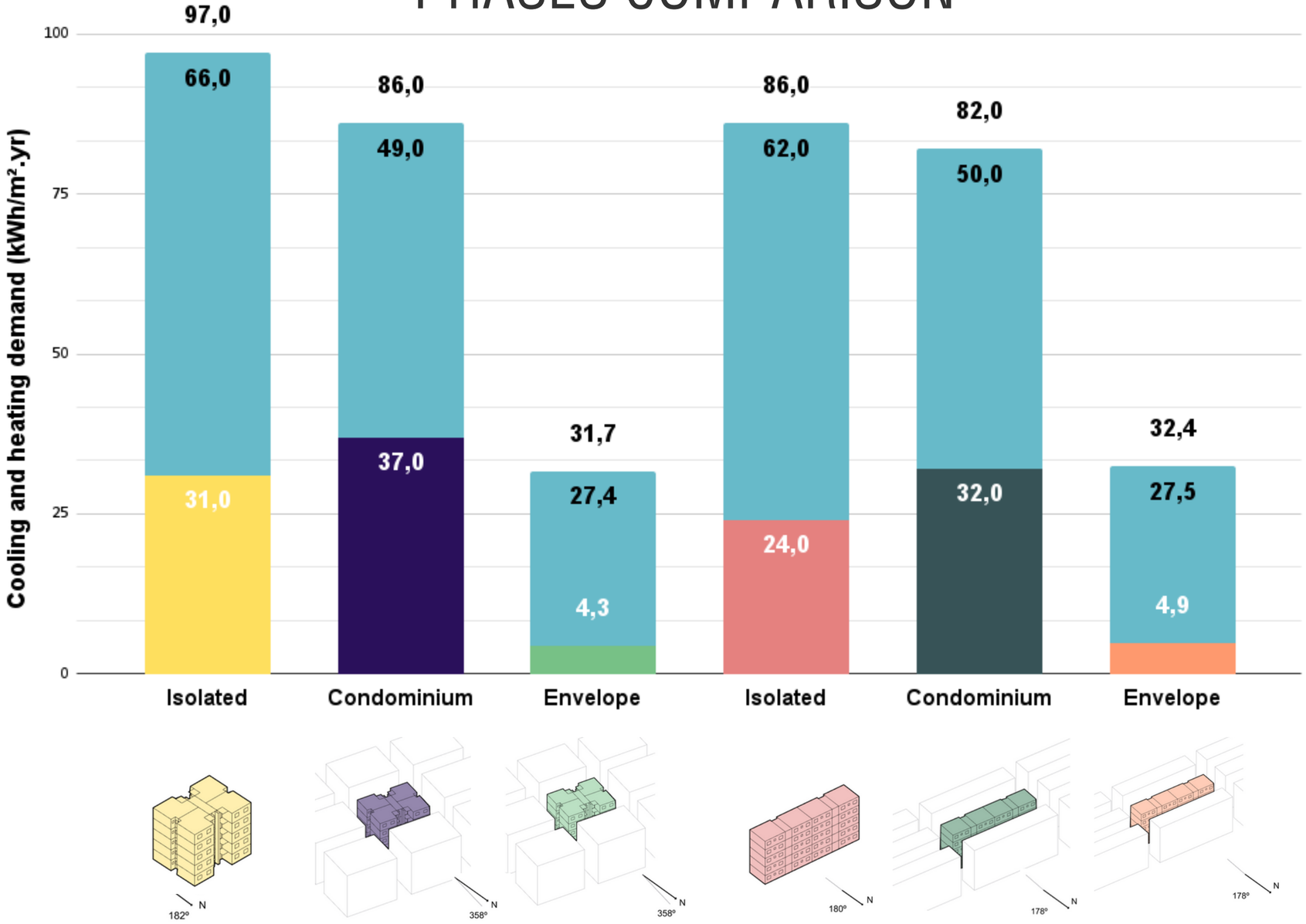
LINEAR BUILDING



PHASE III: ENVELOPE

Optimization variables	Symbol	Corresponding variable	Unit	Range of variability	Condominiun scenario	
					H Building	Linear Building
Solar orientation					358º	178º
Insulation thickness wall (N)	ITN	X6	mm	0 to 150	20	80
Insulation thickness wall (S)	ITS	X7	mm	0 to 150	90	110
Insulation thickness wall (E)	ITE	X8	mm	0 to 150	50	100
Insulation thickness wall (W)	ITW	X9	mm	0 to 150	150	10
Insulation thickness roof	ITR	X10	mm	0 to 1505	100	60
Solar absorptance wall	SAW	X11	-	0.2 to 0.9	0.21	0.20
Solar absorptance roof	SAR	X12	-	0.2 to 0.9	0.24	0.22
Glazing thickness	GT	X13	mm	3 to 10	3	4
Setpoint ventilation	AFN	X14	ºC	5º C	21.6	21.9
Total Energy Demand (kWh/m².yr)					**31.7**	**32.7**

PHASES COMPARISON



CONCLUSIONS

Optimizing multiple variables and balancing heating and cooling is crucial to achieving significant demand reduction of up to 60% in buildings, as demonstrated by this study.

The importance of analyzing multiple variables simultaneously and customizing solutions for buildings, rather than standardizing solutions, for optimal demand reduction.

Utilizing energy-saving techniques, specifically enhancing the thermal envelope, is crucial to mitigate the effects of climate change and address energy poverty in social housing, as there are significant disparities in energy demand between apartments within the same building.

THANK YOU FOR YOUR ATTENTION _

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