A TOOL FOR THE PARAMETRIC ASSESSMENT OF OPERATIONAL ENERGY USE AND EMBODIED GHG EMISSIONS IN A SINGLE-FAMILY HOUSE CONCEPT STUDY

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Introduction

environmental building assessment tools

BREEAM®

One Click LCA

U.S. GREEN BUILDING COUNCIL LEED CERTIFIED USGBC

energy modelling tools

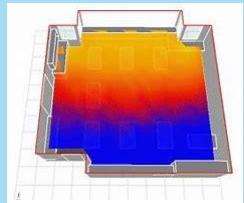
IDA ICE Indoor Climate and Energy

simien

EnergyPlus

parametric analysis tools (PATs)

grasshopper GENERATIVE MODELING FOR RHINO



daysim

Excel based tool

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Introduction

Complexity of the parametric tool has been increased:

old

- insulation thickness: (50), 100, 150, 200, 250, 300 and 350mm
- window types:
  - (3-ply 0.71 W/m2K g-value 0.55, 2-ply 2.6W/m2K g-value 0.78, 3-ply 0.50 W/m2K g-value 0.5, 2-ply 1.30 W/m2K g-value 0.62)
  - 2-ply 2.8 W/m2k g-value 0.78, 2-ply 1.0 W/m2k g-value 0.63, 3-ply 0.5 W/m2k g-value 0.5
- North façade glazing area: 10, 15, 20, (25, 30 and 35)m^2
- South façade glazing area: 10, 15, 20, (25, 30 and 35)m^2

new

- climatic zones: Oslo and Lecce
- solar shading: none, curtains and venetian blinds
- electricity emission factors: 132 and 290 gCO_{2eq}/kWh

- Increased parametric iterations from 1,372 to 12,348.

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Methodology

- Operational energy use has been calculated for the whole building, on a monthly basis, includes heating and cooling lighting appliances, ventilation internal heat gains from people and solar heat gain.
- Embodied GHG emissions have been calculated for the whole building according to EN 15978 and NS 3720 and includes emissions from the production phase and operational energy use. Calculations are structured according to NS 3451 and include groundwork and foundations, load-bearing structure, outer and inner walls, floors, roof, stairs and technical equipment. Functional unit: 'per m^2 of heated floor area per year of building lifetime' ($kgCO_{2eq}/m^2/yr$)

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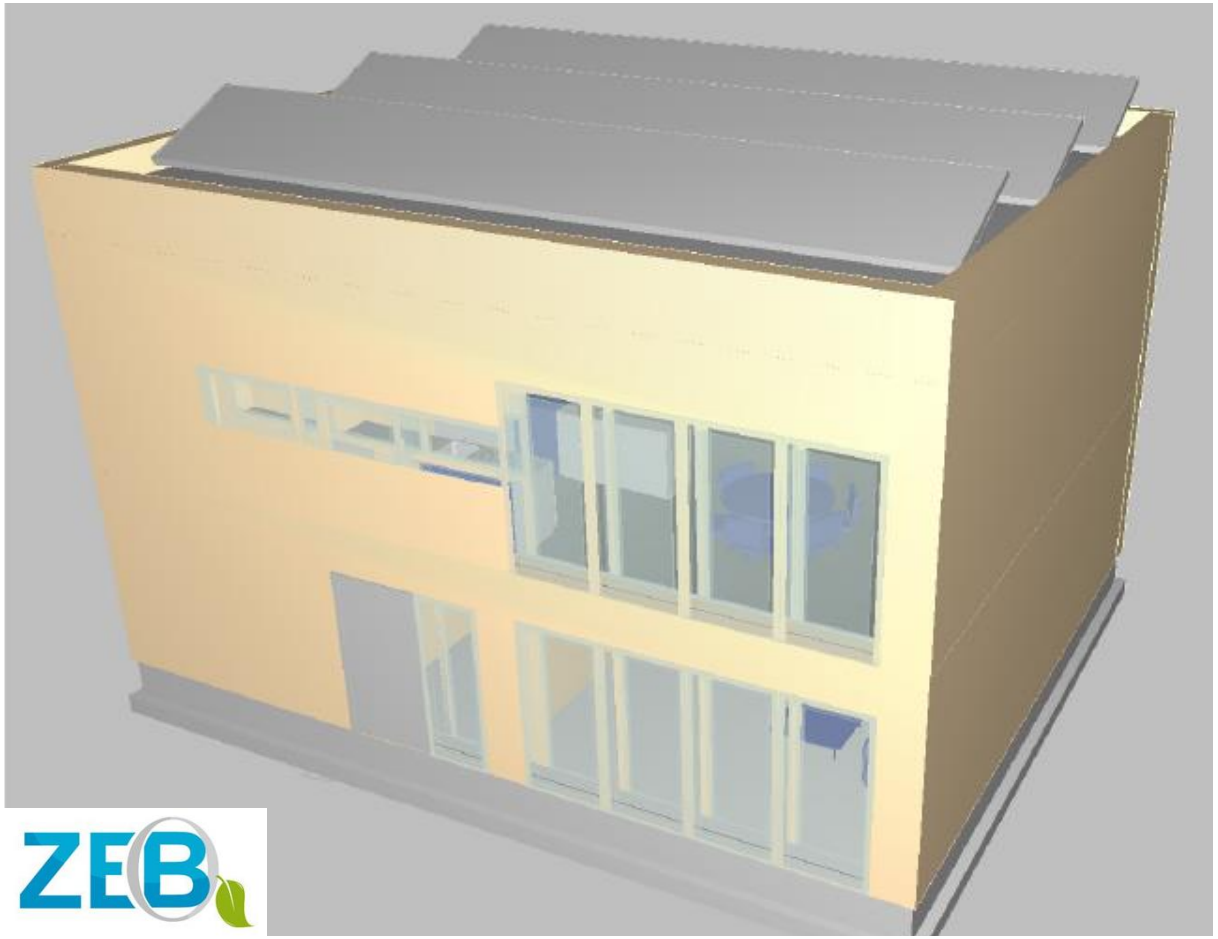
Case study

ZEB single family house (SFH)

- 160 m^2 heated floor area
- 60 years building lifetime
- well-insulated building envelope
- solar thermal collectors
- grid-connected photovoltaics
- air-to-water heat pump
- balanced mechanical ventilation system with heat recovery



https://www.sintefbok.no/book/index/945/a_zero_emission_concept_analysis_of_an_office_building

1st selection of parametric variations

Generates 12,348 permutations

Parameter	Option A	Option B	Option C	Option D	Option E	Option F
Insulation	100mm	150mm	200mm	250mm	300mm	350mm
Window type	2-ply 2.8 W/m^{2}k g-value 0.78	2-ply 1.0 W/m^{2}k g-value 0.63	3-ply 0.50 W/m^{2}k g-value 0.50	-	-	-
North window area	10m^2	15m^2	20m^2	-	-	-
South window area	10m^2	15m^2	20m^2	-	-	-
Solar shading type	No shading	Curtain 0.5 global radiation	Venetian blind 0.08 global radiation	-	-	-
Climate	Oslo	Lecce	-	-	-	-
Electricity mix	Norwegian	European	-	-	-	-

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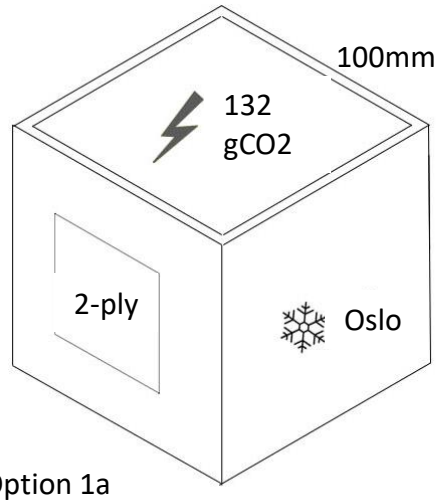
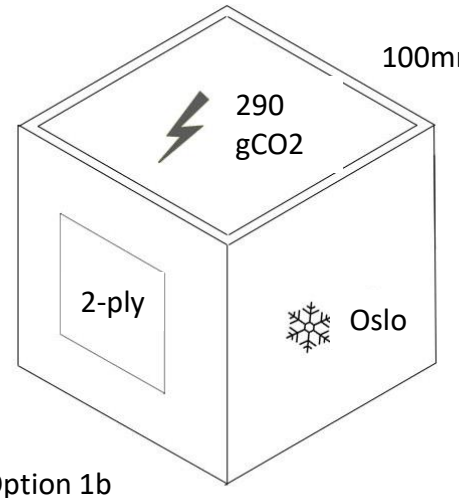
2nd selection of parametric variations

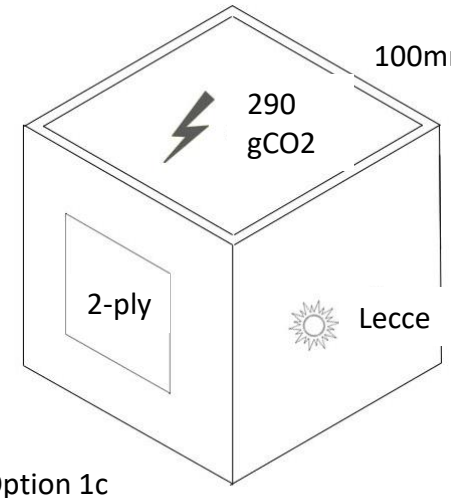
Generates 486 iterations



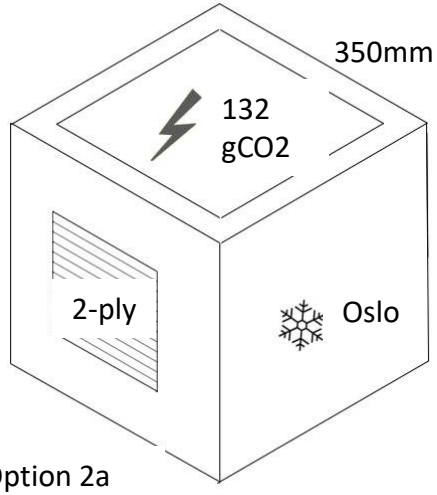
Option 1a



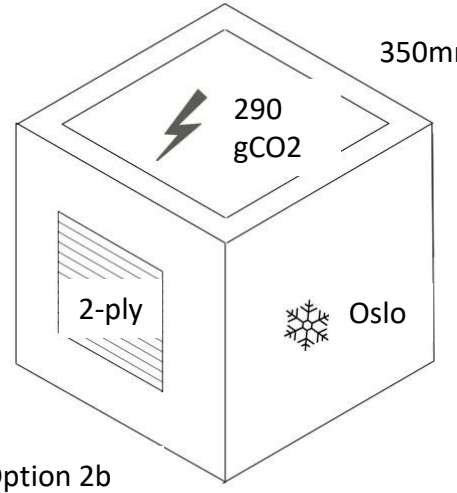
Option 1b



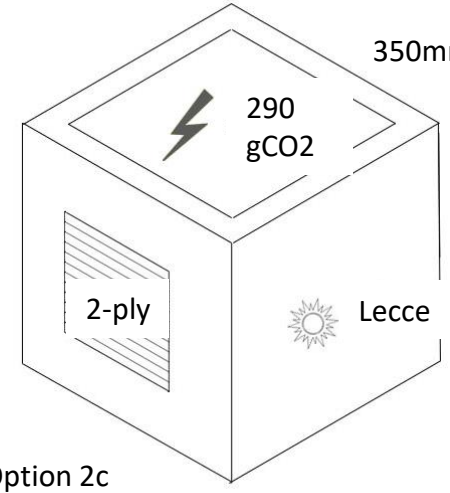
Option 1c



Option 2a



Option 2b



Option 2c

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2nd selection of parametric variations

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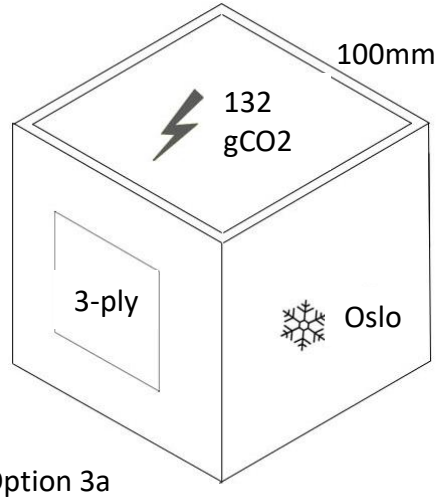

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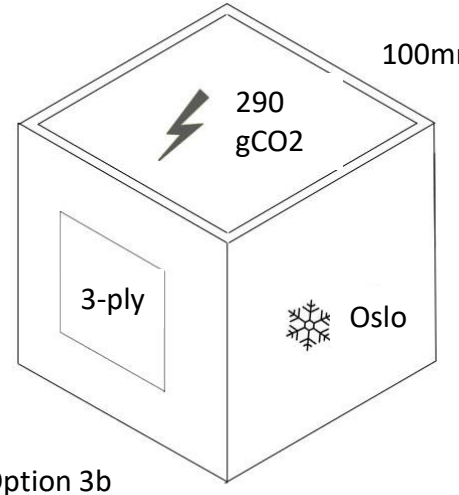
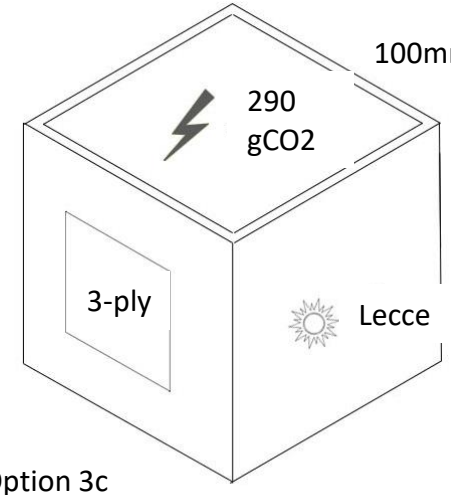
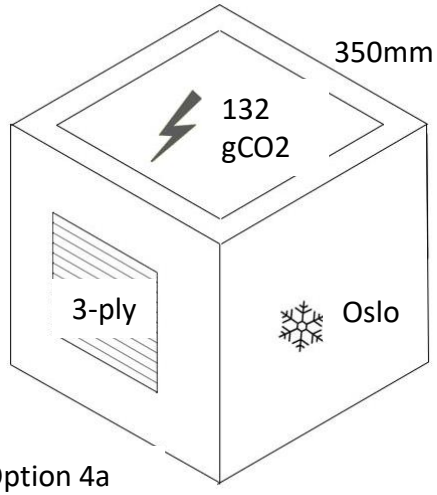


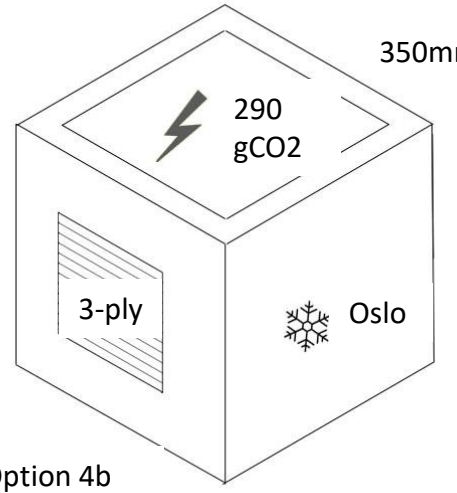
Option 3b



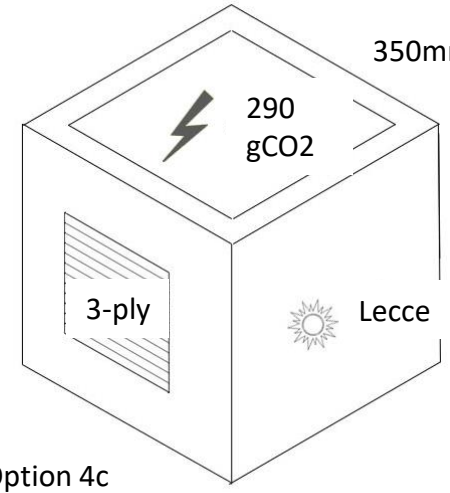
Option 3c



Option 4a



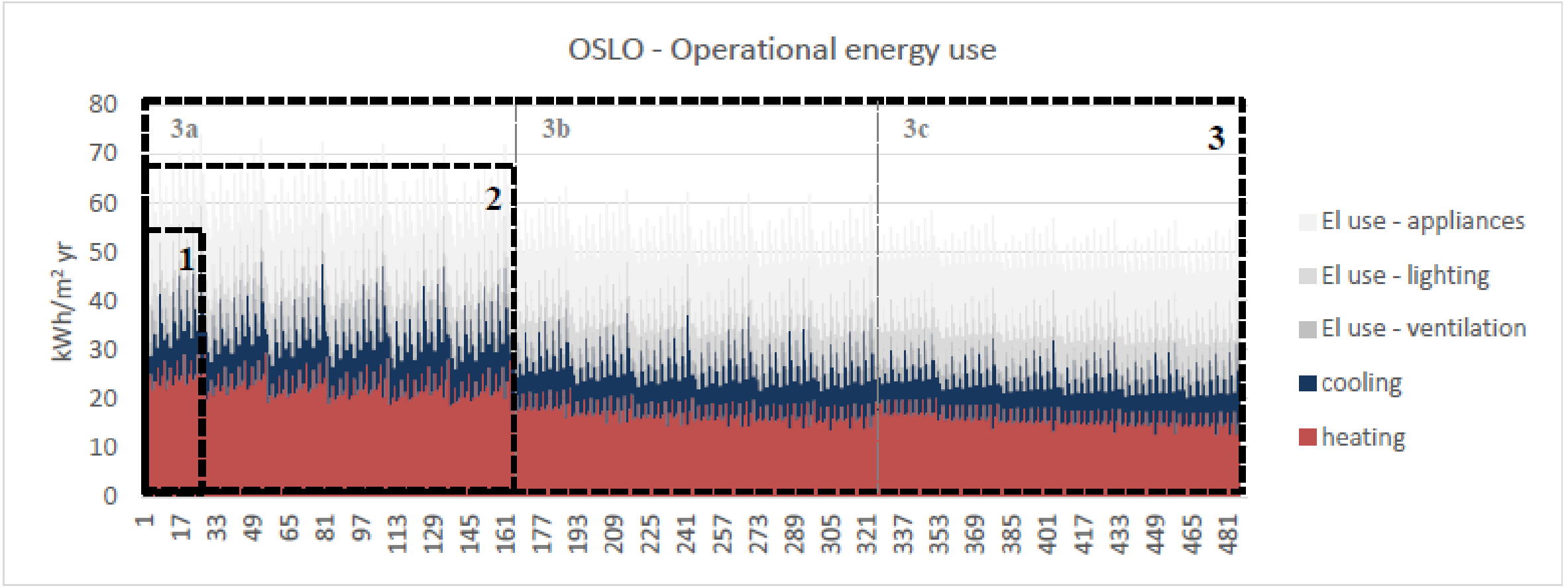
Option 4b



Option 4c

Results

Variables
1. Shading options and glazing areas
2. Plus insulation thicknesses
3. Plus window types



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Results

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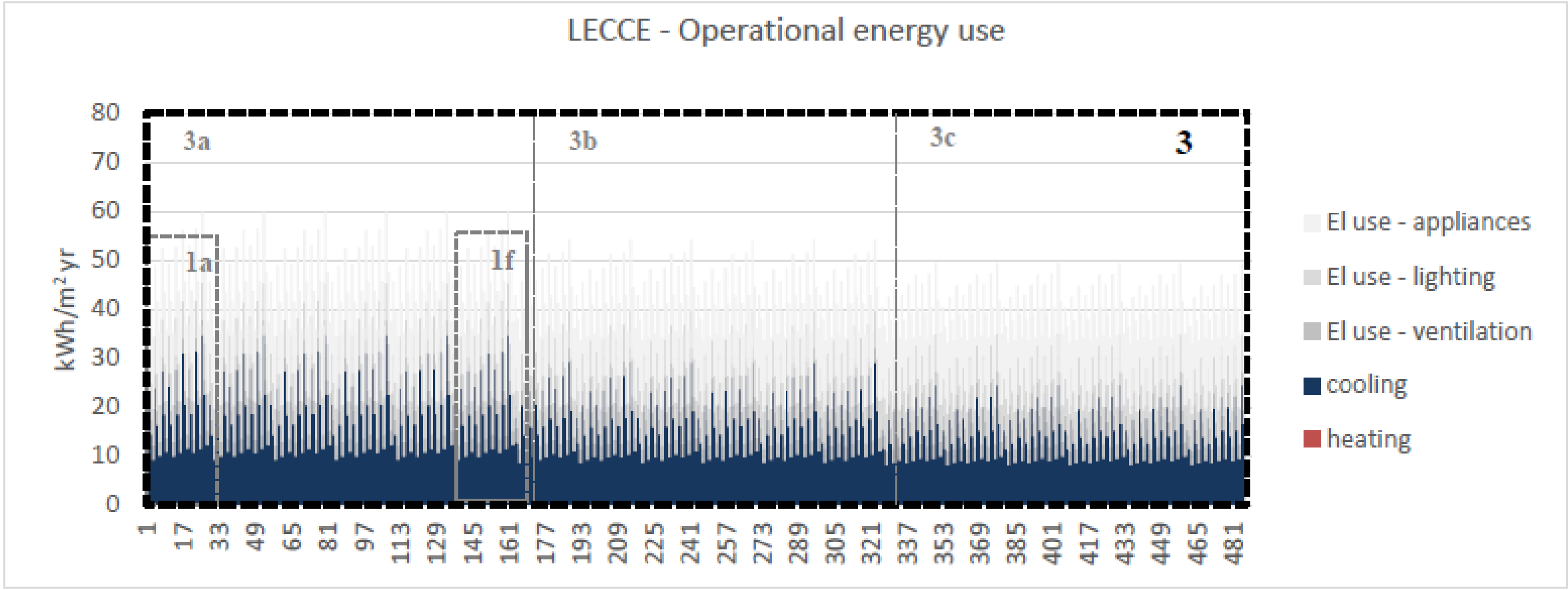

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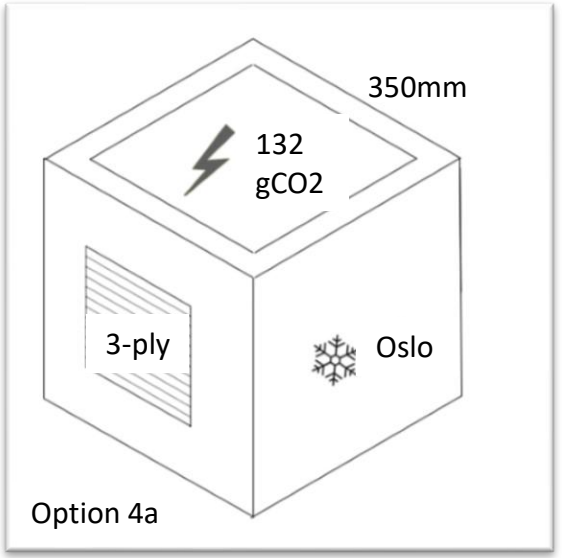
Table 3. Operational energy use and the embodied material emission results from the parametric analysis.

	Heating demand ($kWh/m^2/yr$)	Cooling demand ($kWh/m^2/yr$)	Total operational energy use ($kWh/m^2/yr$)	Operational energy use emissions ($kgCO_{2eq}/m^2/yr$)	Embodied material emissions ($kgCO_{2eq}/m^2/yr$)	Total emissions ($kgCO_{2eq}/m^2/yr$)
Option 1a	25	19	69	9.1	1.6	10.6
Option 1b	25	19	69	19.9	1.6	21.5
Option 1c	0	27	53	15.2	1.6	16.8
Option 2a	25	4	55	7.2	1.7	8.9
Option 2b	25	4	55	15.8	1.7	17.5
Option 2c	0	11	36	10.4	1.7	12.1
Option 3a	18	13	57	7.5	1.6	9.1
Option 3b	18	13	57	16.5	1.6	18.1
Option 3c	0	20	45	13.0	1.6	14.6
Option 4a	17	4	46	6.1	1.7	7.8
Option 4b	17	4	46	13.4	1.7	15.1
Option 4c	0	9	34	9.9	1.7	11.6



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Summary

This study has generated 12,348 parametric permutations, a 10-fold increase on the previous study. The PAT may be used for setting energy and emission performance goals and targets, optimising renewable energy and passive systems, evaluating building envelope schemes, integrating architectural features and integrating building systems.

Future work may include creating algorithms to provide analytical decision support, for example through multicriteria decision-making. Further development may also include expanding the tool to the neighbourhood level, whereby the leap from building to neighbourhood increases the number of parameters and variables exponentially.

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