# Genetic Algorithms Help to Optimise Passive Building Design

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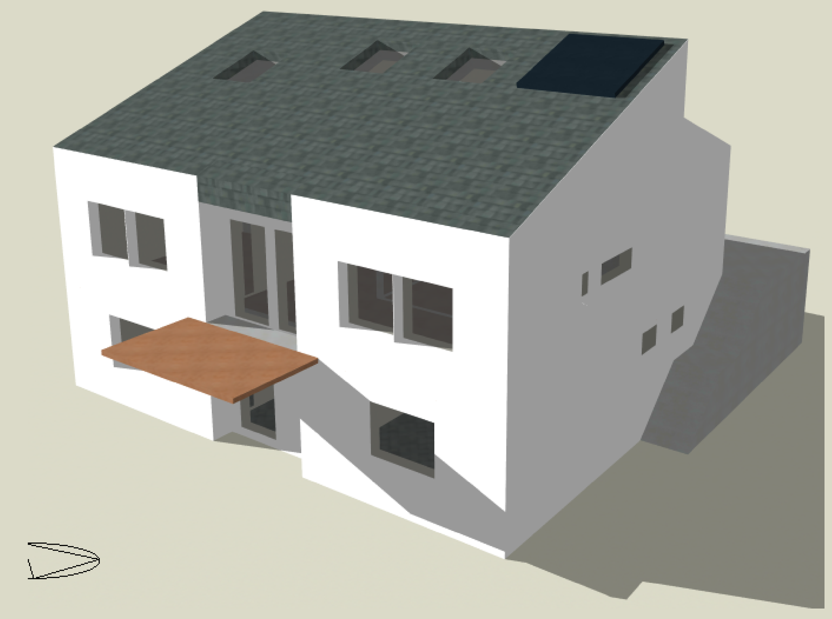
## 1. Introduction

***"There appears to be growing evidence of overheating in homes, particularly for newer homes built to satisfy more demanding standards of energy efficiency" (Zero Carbon Hub, Overheating in homes, 2012)***

### The problem

- Growing use of passive design to meet increasingly demanding energy standards.
- Passive design lowers energy consumption but raises summer overheating risk (increased glazing, insulation and air tightness).
- Simplified "compliance-based" modelling tools cannot evaluate overheating.
- Understanding the trade-off between energy/carbon, cost and comfort using traditional modelling methods is difficult and time-consuming when considering multiple design variables.



**Case-study: Passivhaus 3-bedroom dwelling**

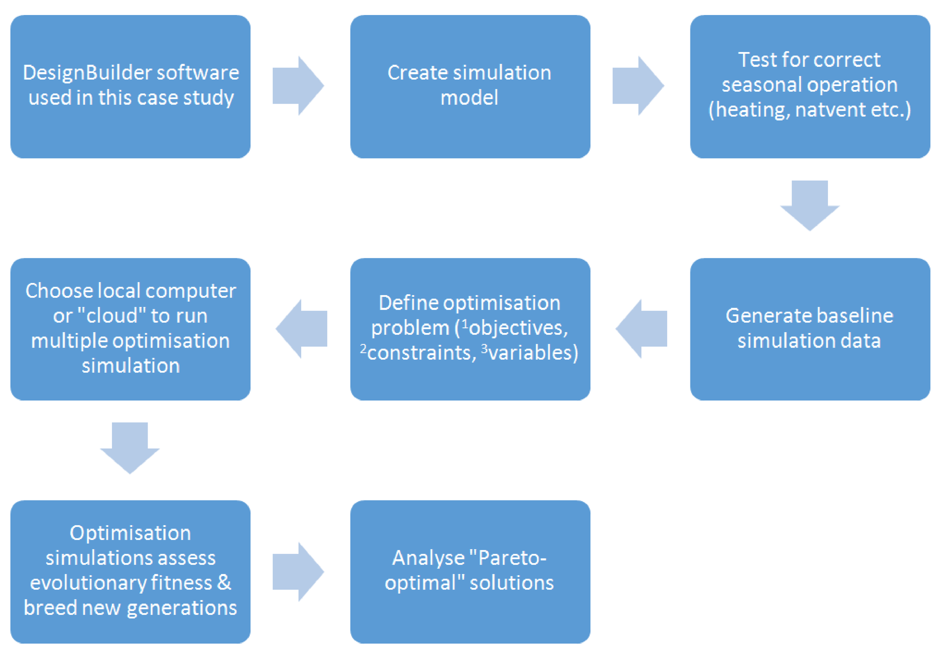
### Our solution

- Using multi-objective optimisation techniques to mimic evolution by natural selection to efficiently find optimum designs when it is too complex to simulate all possible scenarios.
- Multi-objective optimisation using genetic (evolutionary) algorithms is now available in mainstream simulation software including DesignBuilder EnergyPlus.
- Optimisation objectives, constraints and variables have been used to identify the configurations which best meet the design criteria for the Passivhaus 3 bedroom dwelling shown to the left.

## 2. Objectives

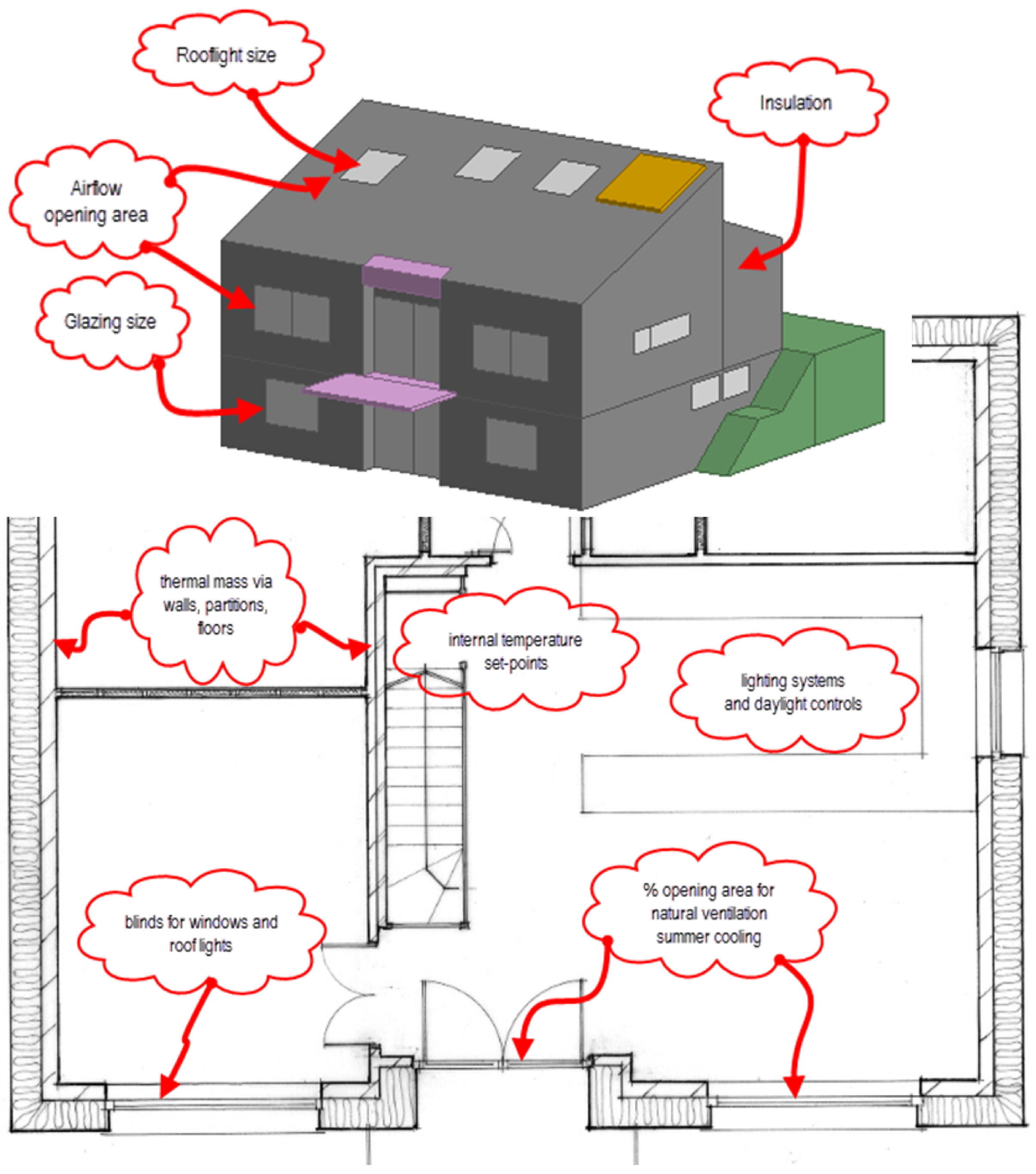
1. To efficiently identify the design parameters (glazing size and opening area, thermal mass etc.) yielding the lowest energy consumption without compromising occupant comfort.
2. To help validate and develop optimisation software using a real case-study with robust data on costs and options.

## 3. Method




Multi-objective optimisation is a process where many simulations are run automatically under the control of an optimiser which favours design options that best meet design criteria and iteratively tests and re-tests new generations of these until the very best set of options have been identified.

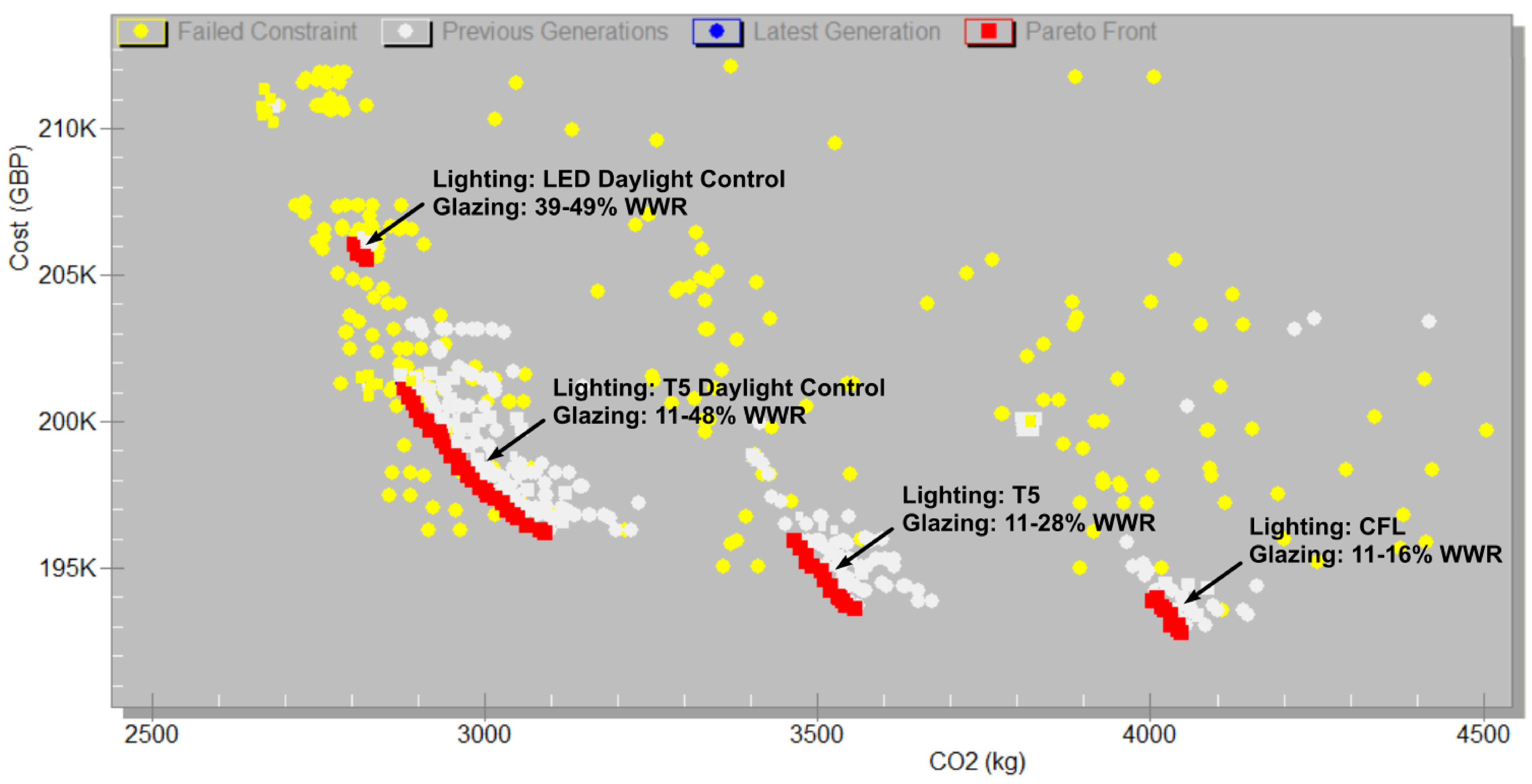
1. Objectives define the "success criteria"... 2 selected were "minimise construction cost" and "minimise CO2 emissions".
2. Constraints define performance limits. 200 hours discomfort used in this case to exclude invalid solutions.
3. Design variables used were:




## 4. Results

The graph below summarises the results from the multi-objective optimisation study. The red points are "Pareto-optimal" in that they cannot be beaten on both "minimise carbon" and "minimise cost" objectives and they respect the maximum 200 hours discomfort hours constraint.

**Optimisation Analysis - Minimise Operational Carbon Emisssions and Construction Cost**




The results show 4 clusters of optimal designs based mainly on the type of lighting system and glazing area. The other common features in the solutions selected as "pareto-optimal" by the optimiser are:

- High mass selected for external walls, ground floor and internal partitions.
- Standard triple glazing is generally indicated except at high cost/high performance points.
- 7-10% window opening area is required to provide adequate summer natural ventilation cooling.
- Insulation levels are dictated by Passivhaus standards and no attempt was made to improve on these in the study.
- Heating (air) setpoint temperatures of 21.5 - 22.0°C minimise winter discomfort based on ASHREA 55.
- Natural ventilation cooling (air) setpoint temperatures 21.0 - 23.0°C minimise summer discomfort, avoiding overcooling based on ASHREA 55.

## 5. Conclusions

- As expected the optimiser indicated that higher than normal thermal mass in external walls, partitions and concrete floors was required to avoid excessive summer overheating.
- Recommended glazing percentages (11-49%) are closer to typical domestic designs than commonly used in Passivhaus designs, helping to avoid summer overheating.
- The clustering of results indicates that lighting type is a key decision. Although the optimisation study puts "T5 with control" at the "sweet spot" on the curve of Pareto optimal points, in reality some degree of lighting control would be naturally provided by occupant behaviour (switching lights on only when it's dark), so the most cost-effective lighting option is likely to be "T5 without lighting control" in practice. Some common sense is still required to interpret results!
- This study enabled many times more simulations to be undertaken to test for optimal design parameters than would have otherwise been commercially viable, and has provided a number of optimised solutions that can now be tested further in their own right. This gives much greater confidence that an optimal design will be provided.
- Being able to see the trade-off between cost and environmental performance graphically allowed design decisions to be made quickly and easily. For example the extra cost of LED lighting relative to T5 can be clearly seen to give a relatively poor return on investment in this study.

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CIBSE ASHRAE Technical Symposium, Dublin, Ireland 3-4 April 2014