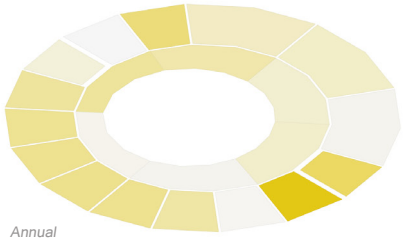
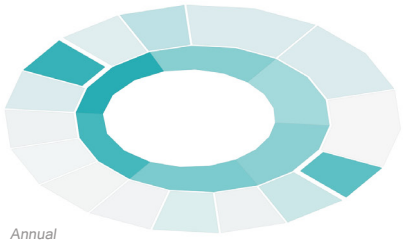
# SUSTAINABLE DESIGN + APPLIED RESEARCH

*Max C. Doelling, Dipl.-Ing.*

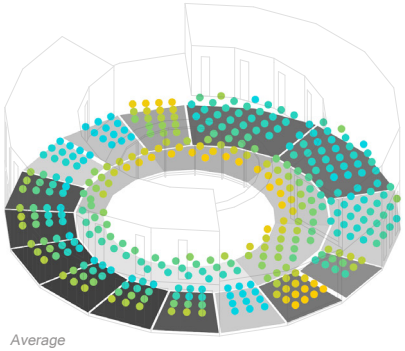
*Entry Stairs; The Hive, Kotagiri, India. A Kundoo + M C Doelling, 2008 - 2012*



*Annual Cooling Energy*



*Annual Heating Energy*



*Average Air Temp. + Daylight*

| | | |
|---|---|---|
| 7 | kWh/m² | 103 |
| 40 | kWh/m² | 136 |
| 18 | °C | 22 |
| 218 | log(lux) | 3870 |

*Interactive Spatial Thermal + + Daylight Visualization*

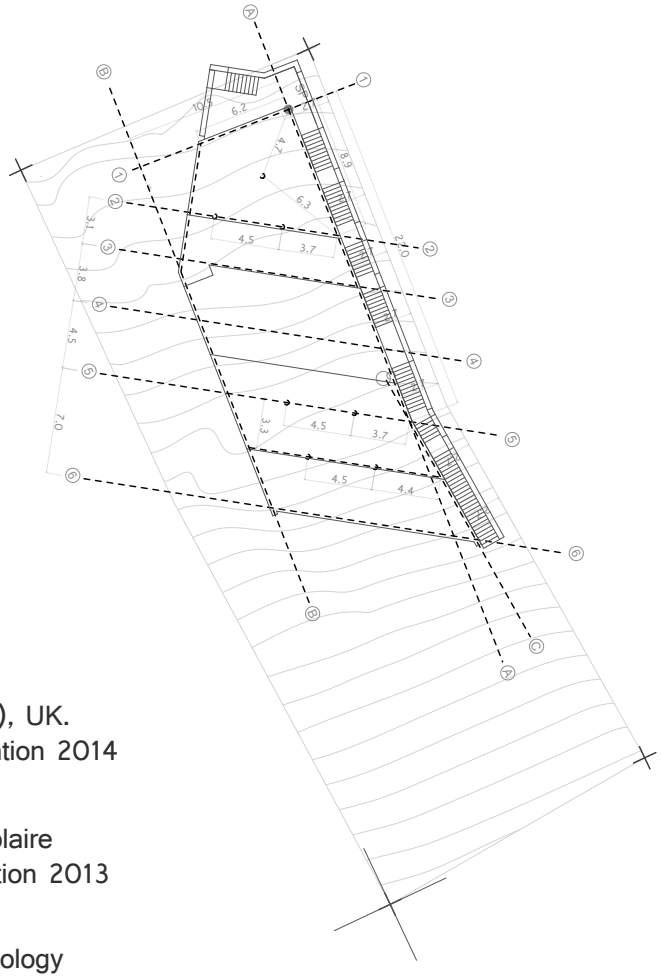
*Custom Software.*
*M C Doelling 2013 - 14*

# SUSTAINABLE DESIGN + APPLIED RESEARCH

*Selected Papers & Presentations*

| *See Arch. Portfolio* | **Project** | **Client** |
|---|---|---|
| *p. 3 - 15*<br>*Accepted proposal* | South Florida Wildlife Center Redevelopment<br>Ft. Lauderdale, FL, USA | The Humane Society<br>of the United States |
| *16 - 27*<br>*Built design* | The Hive, Honey and Coffee Manufactory<br>Kotagiri, Tamil Nadu, India | The Keystone Foundation<br>*Setting Out Plan on Contours; The Hive .....* |
| *28 - 37* | Post Suburbia<br>Cape Cod, MA, USA | Independent study |

| | **Publication** | **Venue** |
|---|---|---|
| *38 - 50*<br>*Peer-reviewed paper* | Space-based Thermal Metrics Mapping for Conceptual Low - Energy Architectural Design | University College London (UCL), UK. Building Simulation and Optimization 2014 |
| *51 - 60*<br>*Peer-reviewed paper* | Parametric Design: a Case Study in Design - Simulation Integration | Institut Nationale de l'Énergie Solaire (INES), France. Building Simulation 2013 |
| *61 - 66*<br>*Invited presentation +*<br>*+ Peer-reviewed paper* | Hybrid Daylight Models in Architectural Design Education +<br>+ Prototyping Daylight | Massachusetts Institute of Technology (MIT), MA, USA. DIVA Day 2012.<br>National University of Singapore (NUS). CAADRIA 2013. |



# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 38 | Cognition Support for Low-Energy Conceptual Architectural Design*

- Custom software developed based on design/sim experiments
- Tested and evaluated in specialized design optimization classes
- Publication: Building Simulation & Optimization 2014, London

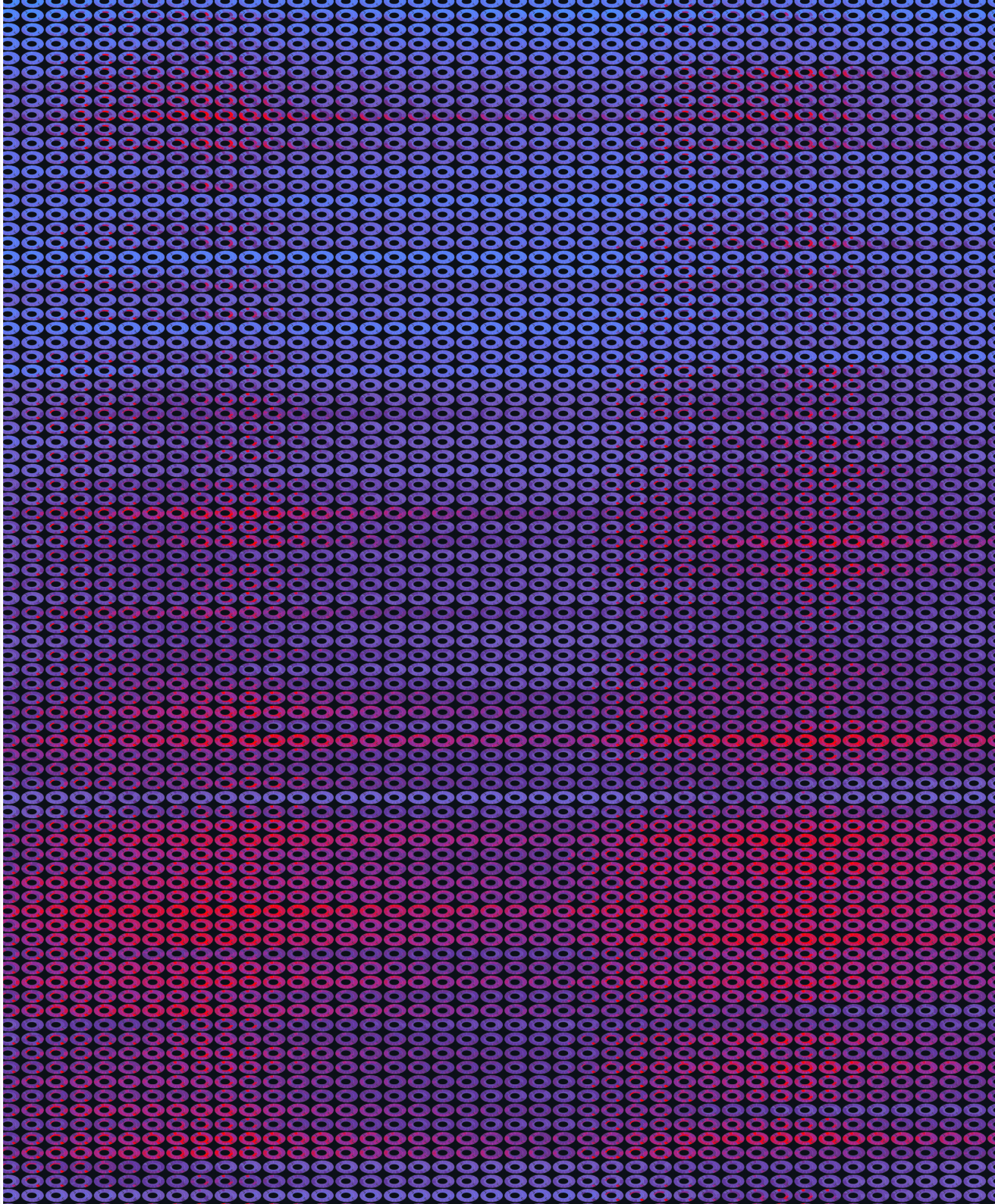
Based on integrated design/simulation workflow observations from interdisciplinary classes held by colleagues and me, a new process model empirically developed from them and the insight that hybrid design/performance representations shape cognition in low-energy architectural design, I developed a spatial thermal and climate-based daylight data analysis/visualization plugin for Rhinoceros3d/Grasshopper3d, dubbed Mr.Comfy.

Instead of using charts or tabular formats, energy consumption, comfort, illuminance levels and any other available performance report variable are directly displayed through color-coded surfaces (and numeric values) where they occur – in the individual spaces of a design. Mr.Comfy bridges the gap between sustainable designers' need to analyze data spatially but still retain numeric precision and multiple data representation modes as typically exposed through traditional graphing.

The tool's features and user case studies are published in several project publications and invited presentations, most notably at Building Simulation and Optimization 2014 in London, at the École Polytechnique Fédérale de Lausanne in Switzerland and the NYC IBPSA chapter, USA.

All publications are available in full on my visualization software website: http://mrcomfy.org/?page_id=116

*Background/Opposite:*
*Annual Hourly Map of All-Zone Average Air Temperatures (excerpt), Sample Building, Climate: Berlin*



# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 39 | Rhinoceros/Grasshopper3d Integration for Improved Design-Analysis Interaction*

By color-mapping and visually reinforcing differences between zone behaviors, designers and engineers can more easily diagnose which parts of a building use more energy and answer fine-grained analysis questions. Mr.Comfy's features include:

- Spatial color-mapping of EnergyPlus *.csv zone report variables
- Spatial co-mapping of Daysim daylight and irradiation results
- Automatic generation of fitted or custom gradient display bounds
- Interactive hourly scheduling & custom report time ranges
- Generate average, sum report maps and discover data extremes
- Map percentages of hours that meet custom conditions
- Custom report variable creation through component instantiation

Shown to the right is a custom mapping scenario for one floor of a circular sample office building in Berlin, Germany:

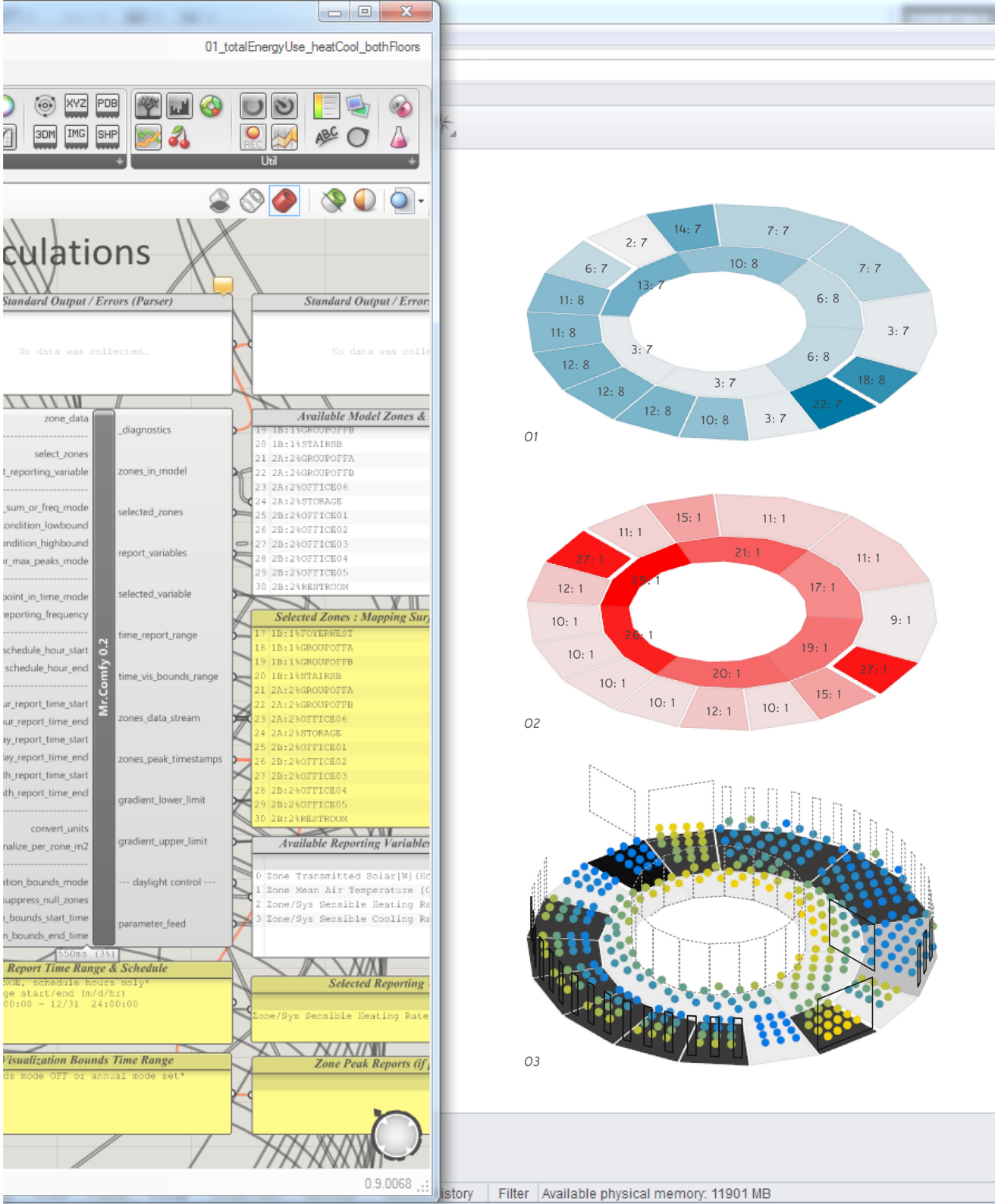
*01:* Custom Search, Zone Highest Monthly Cooling Energy Use kWh/m²: month timecode; Schedule: 24 hrs.

*02:* Same as previous, but for heating energy use

*03:* Average of Total Daytime Zone Internal Latent Gains, kJ/m² Illuminance Distribution, log(lux), Schedules: 8 - 20 hrs.

To analyze the interplay of internal and external gains and how they are mediated through the building fabric (e.g. glazing areas, shown dotted to the right) is a first step to understand where specific load scenarios occur- and how to reduce their severity.

| | | | |
|---|---|---|---|
| Cooling Energy Use | 2.22 | kWh/m² | 22.17 |
| Heating Energy Use | 8.54 | kWh/m² | 28.7 |
| Avrg. of Total Internal Lat. Gains | 3.93 | kJ/m² | 9.32 |
| Log. of Avrg. Illuminance | 382 | log(lux) | 6733 |



# SPACE-BASED THERMAL METRICS VISUALIZATION

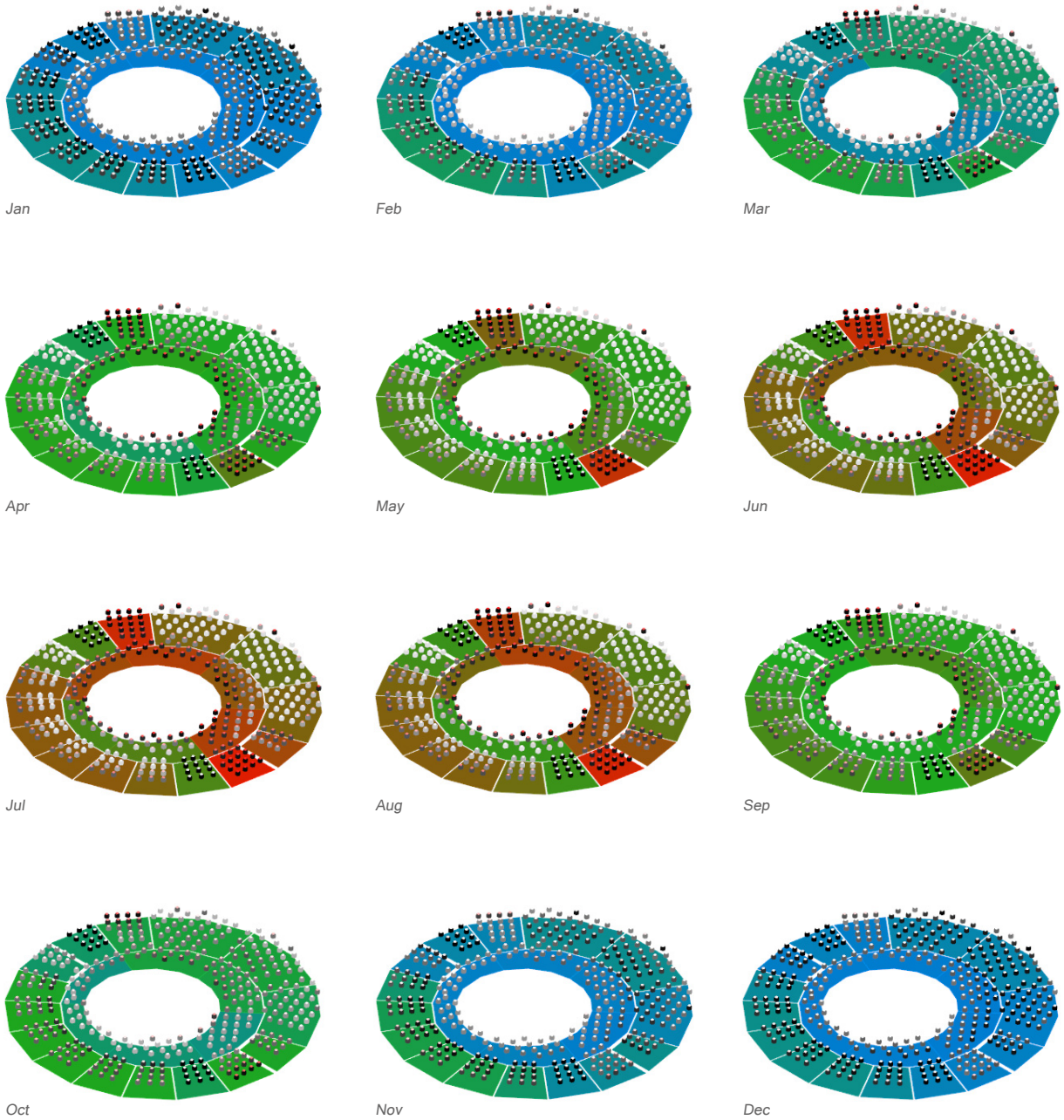
*p. 40 | Animation, Multi-Timestep Mapping for Seasonal Performance Analysis*

The combination of several data mapping types with temporal animation can reveal a surprising amount of building behavioural information that is not always easy to understand through traditional means; Mr.Comfy's zone-based display makes it easier to attain an overview and focused explorations of what is happening in both thermal and daylight domains.

Through instantiating several Mr.Comfy components it is also possible to create custom metrics; the monthly overview map of the sample building's first floor (right) simultaneously overlays mean radiant temperature display with two daylight metrics.

Black to white dots show the percentage of selected hours when zone illuminance is within 300 to 2000 lux- an acceptable range; white to red inset display sensor nodes show the frequency of overlit hours. In effect, when overlit tends towards null and illuminance is in a usable range, the contrast between metrics is diminished (white on white) and a quick daylight check possible.

A recommendation to improve the sample building's performance would be to reduce part of the yard's north-facing glazing area, include window shading on its south-facing part and introduce overhangs to the south office windows. Both winter heat loss and summer solar gains are problematic in this building; the high incidence of summer overlit areas indicates that there is leeway to improve thermal performance and daylight utilization, by e.g. reconsidering the window-to-wall ratio (esp. in the yard).




| | | | |
|---|---|---|---|
| Zone Average Radiant Temperature | 14 | °C | 31 |
| Illuminance 2000 - 100,000 lux | 0 | % set hrs. | 100 |
| Illuminance 300 - 2000 lux | 0 | % set hrs. | 100 |

# SPACE-BASED THERMAL METRICS VISUALIZATION

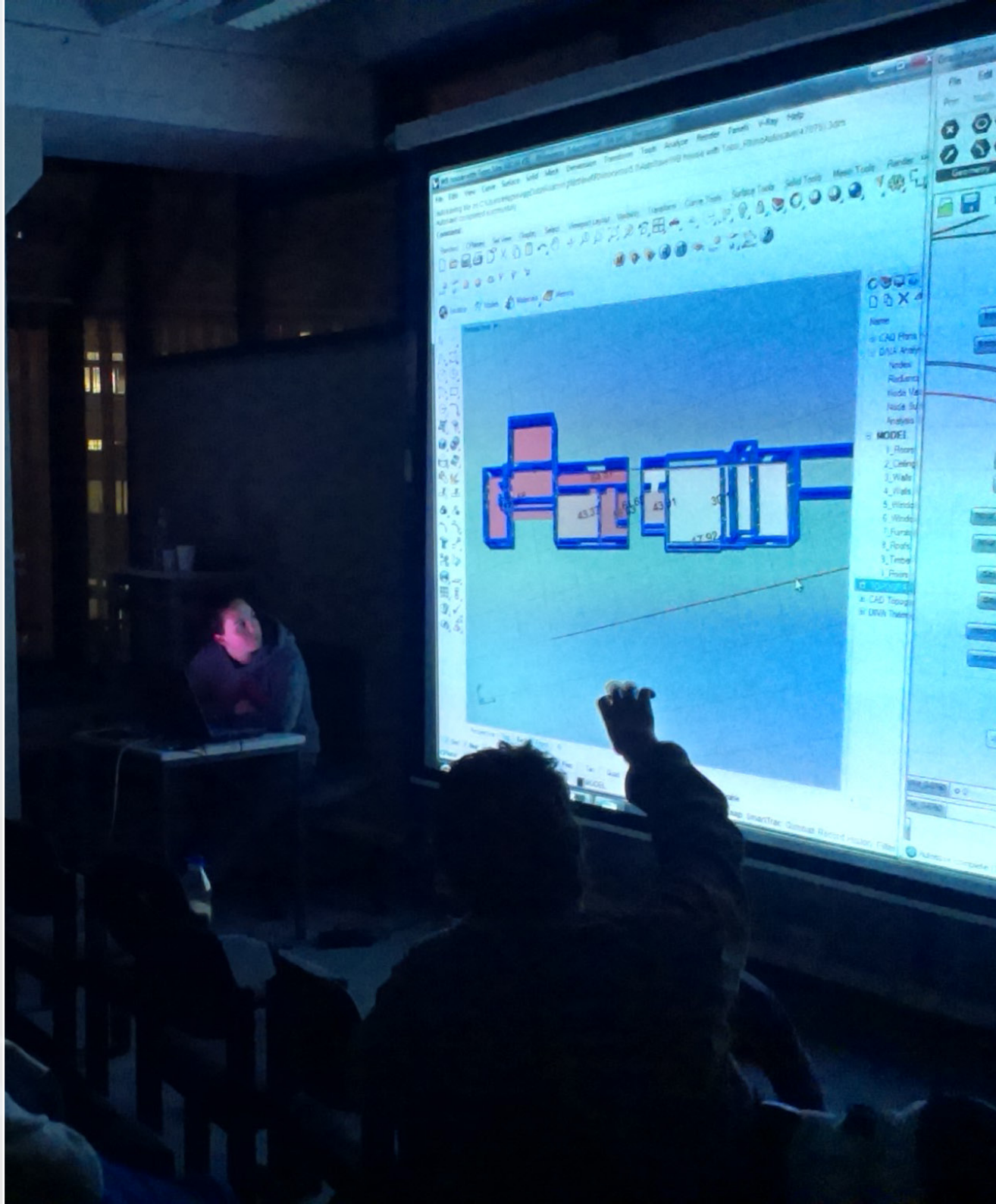
## *p. 41 | Academic Performance Mapping + Optimization of Student Designs*

To explore the use of the tool in actual design scenarios, a class was held during my tenure at the TU Berlin in which student designers mapped and optimized already energy-conscious buildings created in previous simulation-integrated studios.

Testing the tool in unconstrained use allowed for many improvements to be added on the fly, new features to be prototyped and design process observations to be made, which will influence integration model concepts in upcoming studies and classes.

Surprisingly, almost all participants managed to again improve the performance of their designs; a zone-based approach facilitated to finally gain a spatial understanding of simulation results, which is a first step to optimize further. Some of the resulting explorations are shown in the following pages.

Finally, a survey was held to exactly discover users' thoughts about the tool and its underlying spatial mapping principles, results of which are published in a paper presented at Building Simulation and Optimization 2014, London, UCL.



*Background/Opposite:*
*Student Sophie Barker presents Mapping Case Study of Waratah Bay House, Winter 2013/2014, TU Berlin, Germany*

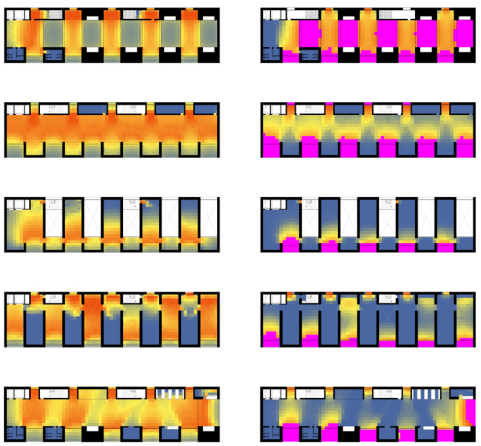
# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 42 | ROBUST Studio Design Reoptimization*
*Design: C. Sitzler, L. de Pedro; Sim. Prof.: Author*

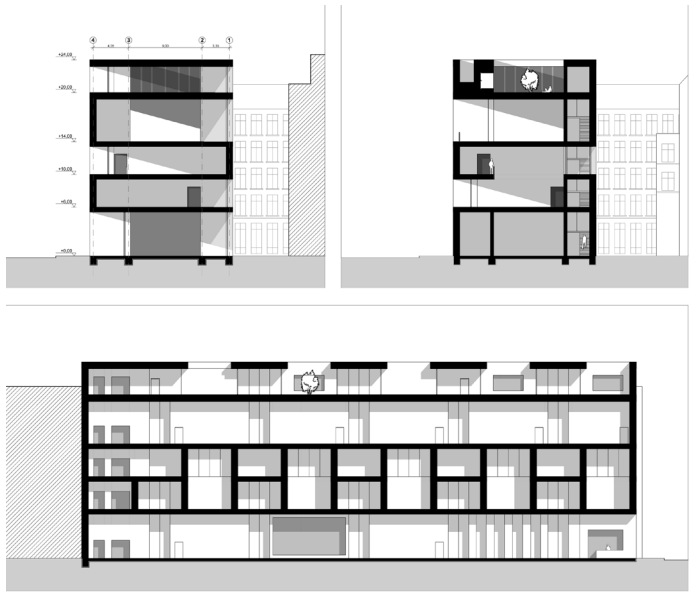
A design from the simulation-integrated ROBUST studio also featured in this portfolio, students were in the mapping class tasked with once again improving design performance aided through visualizations created with Mr.Comfy.

As the ROBUST designs were already highly energy-conscious, this served as a good proving ground to discover whether cognition can be further enhanced by new mapping technologies.

The design shown here, by Christopher Sitzler and Laura de Pedro, already performed comparatively well; its concept of using infra - lightweight concrete to form structural bays of alternating zones of dark and light was through simulations convincingly shown to work as intended; however, as discovered in the following, performance deficits remained and were discovered through mapping.

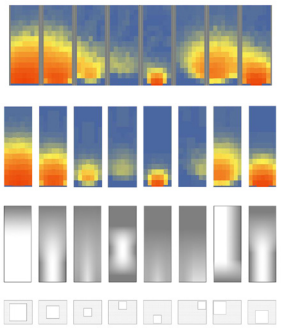



*Daylight studies for alternating contrast situations*

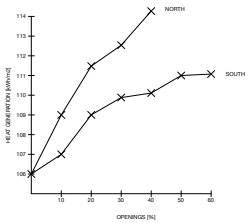


*Cross Sections*

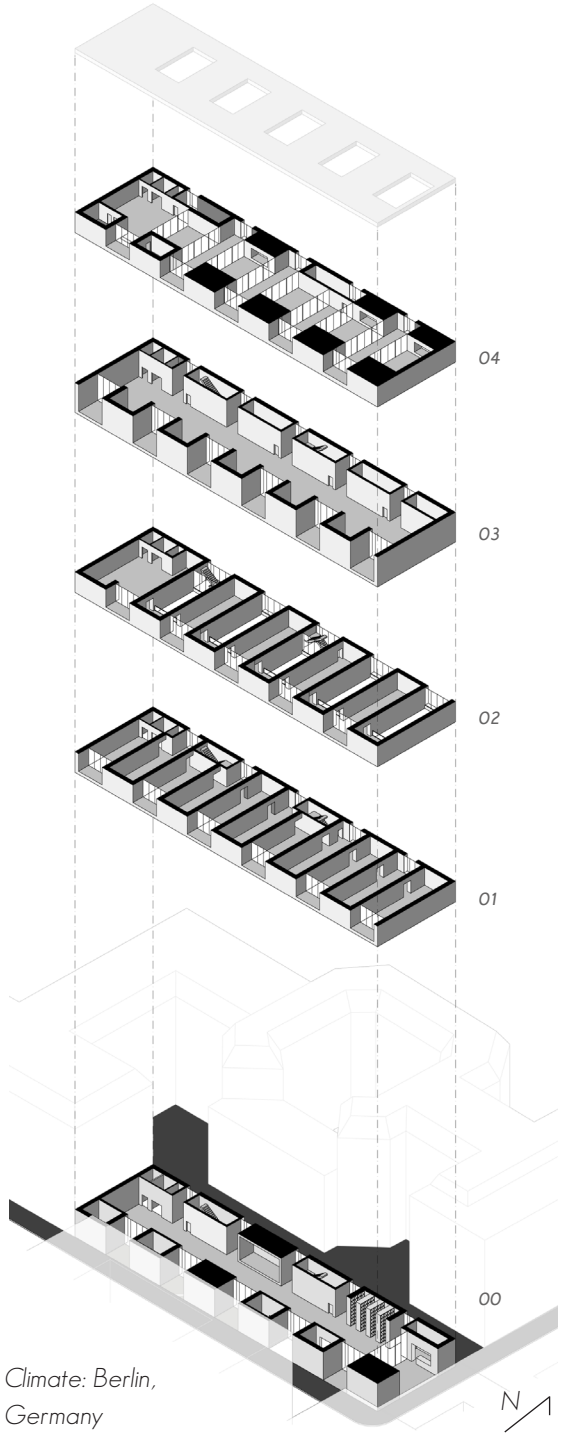
*Lateral Section*




*Intended interior daylight volumetrics (greyscale) vs. simulation results*




*Window to wall ratio effect on heating energy use studies*




*Climate: Berlin, Germany*

# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 43 | ROBUST Studio Design Reoptimization*
*Design: C. Sitzler, L. de Pedro; Sim. Prof.: Author*

An all-zone mapping of the ROBUST design especially revealed problems on the top building floor, where staff offices are to be located. Some concerns about this configuration had already been raised during the initial studio, but were delegated to a low priority and did not skew the overall positive energy balance of the original scheme. Re-mapping of whole-building performance, however, made the top floor problems hard to ignore:

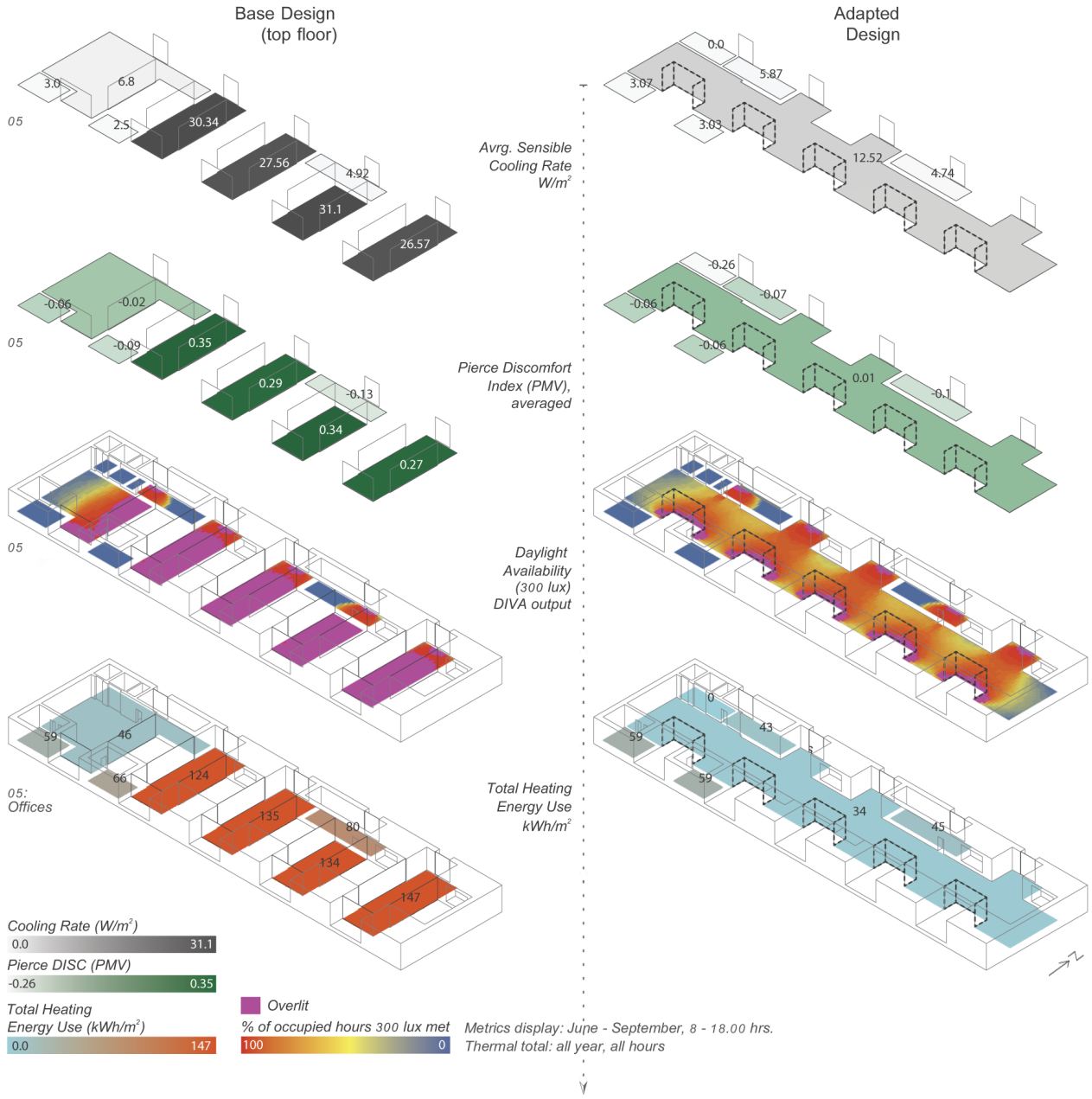
- East/West-facing office plate glass is overdimensioned
- Discontinuous office layout increases exposed total facade area
- Shading was tested, but performance problems remained
- Summer PMV slightly uncomfortable, high cooling energy use
- High winter heating energy use due to fabric losses
- Spaces largely overlit, especially in summer, with glare risk

Based on the analysis maps, students implemented a number of geometric changes to get energy use and comfort under control:

- Merge top floor into one continuous space, facing south
- Reduce overall glazing area, offer shielded balconies, overhangs
- Improve north-facing glass U-values, add low-e coating on south

The measures improved thermal comfort, more than halved cooling energy consumption and reduced heating energy use by a projected 100 kWh/m²; daylight availability was brought from an almost entirely overlit state to more than 80% of the redesigned space being lit by daylight alone during the summer.

*Opposite (this and next page):*
*Multi-Metric Mapping of ROBUST Design Top Floor Base State + Optimization*
*Simulations: C. Sitzler + Author; Simulation Checking, Maps: Author*
*Source: Building Simulation & Optimization 2014 paper (see bibliography)*



# SPACE-BASED THERMAL METRICS VISUALIZATION

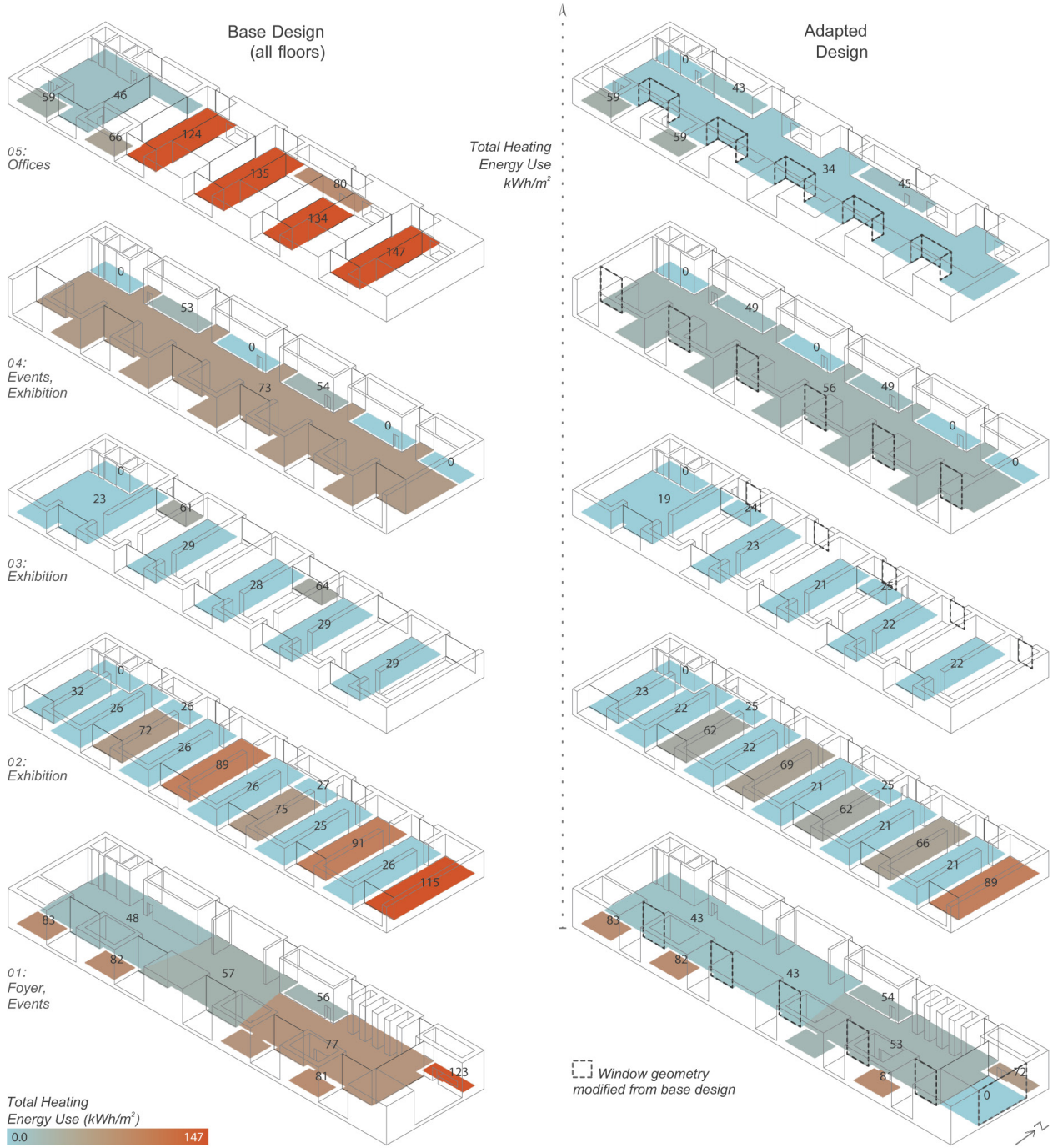
*p. 44 | 'ROBUST' Studio Design Reoptimization*
*Design: C. Sitzler, L. de Pedro; Sim. Prof.: Author*

Apart from the (literally) glaring problems on the top floor, intermediate floors also had some improvement potential. The explorations here especially focused on heating energy use reduction; cooling was checked but found to be by far the lowest energy use factor. To lower heating energy demand, students combined geometric and material tweaks:

- Change ground floor lobby glazing amount
- Add unconditioned lobby buffer space
- Reduce north-facing "picture window" area
- Improve U-Value of remaining north glazing

While not as dramatic as the top floor performance improvements, overall heating energy consumption was still lowered considerably - especially in the lobby spaces - while touching few of the south windows important for daylighting. The design's concept to have dark and daylit spaces alternate when traversing the building on the long axis made the optimizations more straight-forward.

In the maps, combined geometric and material improvements show as greater "jumps" in scale than the linear improvements made through material changes only. Compound changes like these often occur in design and are hard to track, since zones are mutually influential; being able to locally, visually pin down performance effects of complex changes is one reason why spatial performance mapping, as found in class, is highly useful in conceptual design. Furthermore, error checking in large models becomes easier, too, since when zones behave radically different from similar ones, something tends to be amiss, and is easily visible in performance maps.



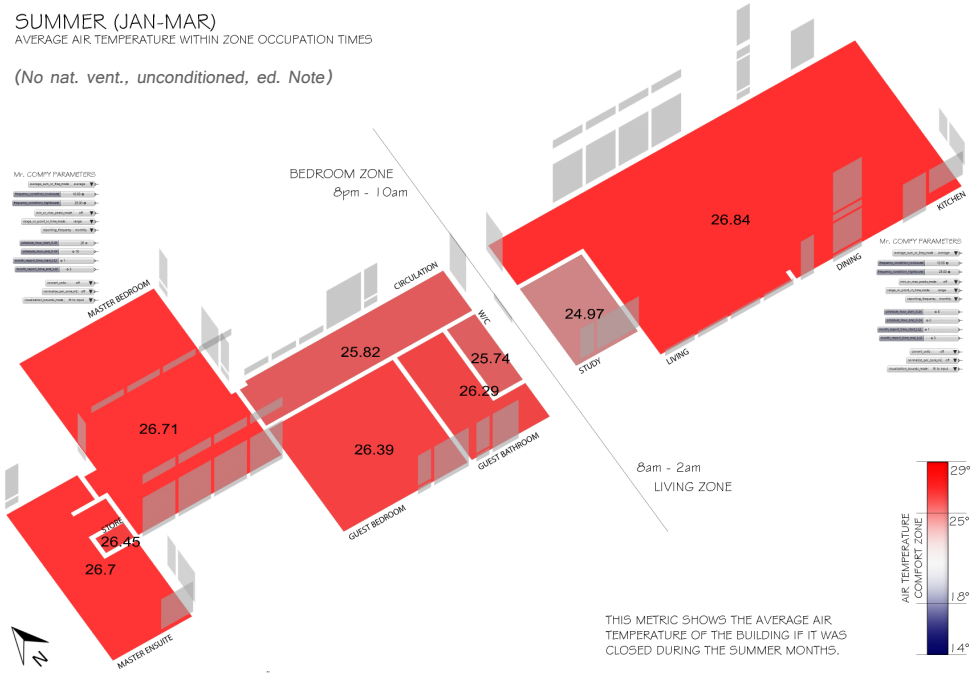
# SPACE-BASED THERMAL METRICS VISUALIZATION

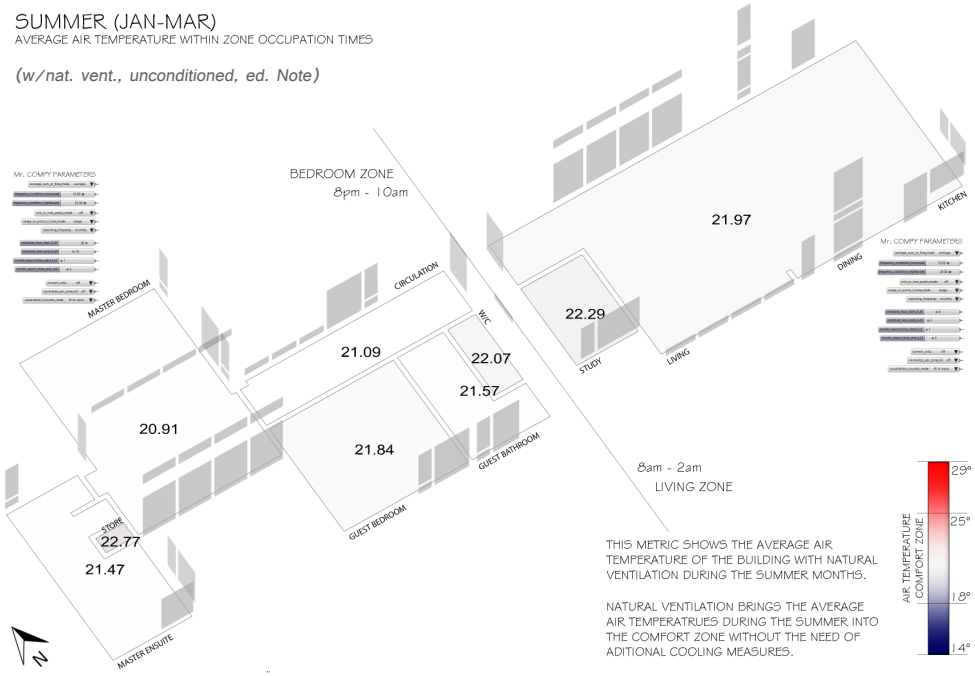
*p. 45 | Waratah Bay House Performance Mapping*
*Modeling, Simulations: S. Barker; Sim. Prof.: Author*

One of the first studies performed, Sophie Barker mapped the performance of an existing structure in South Australia (near Melbourne). Due to her lived experience in the structure, she was able to calibrate the energy model until it corresponded with her real-world subjective thermal assessments.

The visualization/analysis strategy followed several steps:

- Map seasonal air temperatures, with and without natural ventilation
- Use different occupation schedules for bedroom and living room blocks
- Use energy mapping to discover zones with highest total demand
- Peak mapping to understand when highest demand occurs



# SPACE-BASED THERMAL METRICS VISUALIZATION

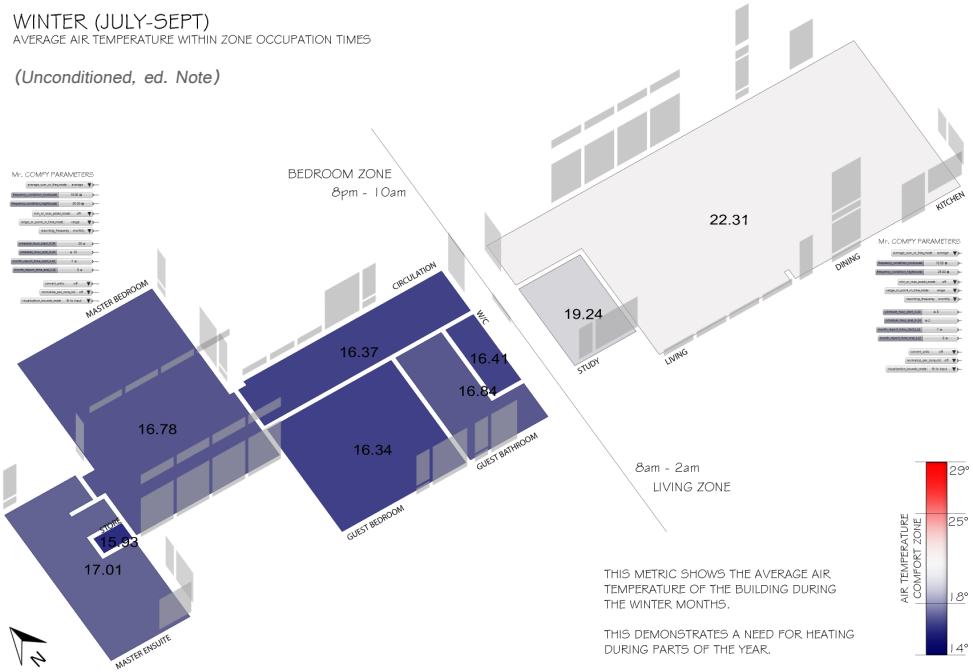
*p. 46 | Waratah Bay House Performance Mapping*
*Modeling, Simulations: S. Barker; Sim. Prof.: Author*

The analysis visualization showed many of the effects already observed in real life; during summer, the building performs adequately if unconditioned and natural ventilation is employed- for both daytime and nighttime schedules. Only in winter there is heating energy demand, especially in the bedroom zones. As is apparent from the maps, the comparative lack of thermal solar gains in the bedroom block (which is oriented South, facing the sea) tends to cause colder nighttime air temperatures. The peak heating wattage maps show when this occurs and can be used to size on-demand heating equipment, which is slated to be included in the structure. Optimization mapping was not part of this particular case study; as the first actual test of the tool, we instead focused on first understanding what mapping can do to improve analysis.

## WINTER (JULY-SEPT)

AVERAGE AIR TEMPERATURE WITHIN ZONE OCCUPATION TIMES

*(Unconditioned, ed. Note)*

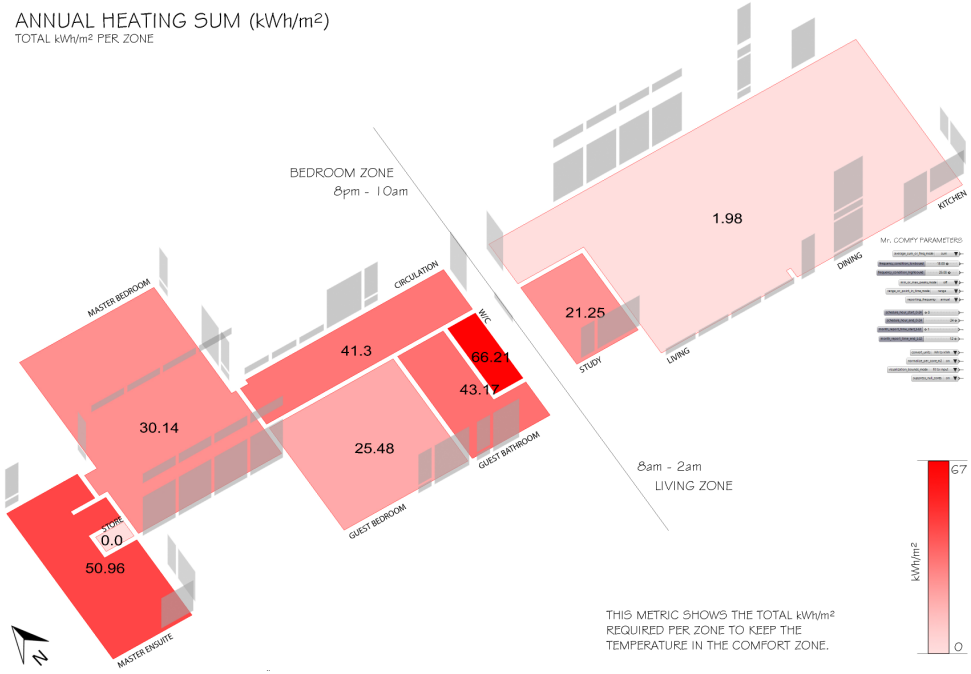



THIS METRIC SHOWS THE AVERAGE AIR TEMPERATURE OF THE BUILDING DURING THE WINTER MONTHS.

THIS DEMONSTRATES A NEED FOR HEATING DURING PARTS OF THE YEAR.

## ANNUAL HEATING SUM (kWh/m²)

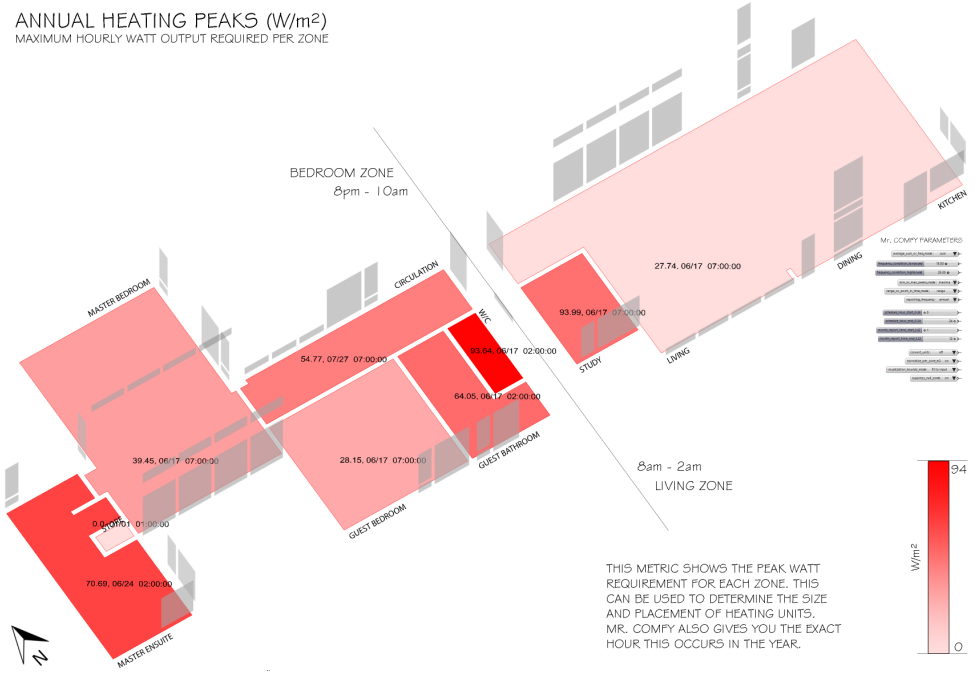
TOTAL kWh/m² PER ZONE




THIS METRIC SHOWS THE TOTAL kWh/m² REQUIRED PER ZONE TO KEEP THE TEMPERATURE IN THE COMFORT ZONE.

## ANNUAL HEATING PEAKS (W/m²)

MAXIMUM HOURLY WATT OUTPUT REQUIRED PER ZONE




THIS METRIC SHOWS THE PEAK WATT REQUIREMENT FOR EACH ZONE. THIS CAN BE USED TO DETERMINE THE SIZE AND PLACEMENT OF HEATING UNITS. MR. COMFY ALSO GIVES YOU THE EXACT HOUR THIS OCCURS IN THE YEAR.

# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 47 | Sweden Urban Housing Design Exploration*
*Design: B. Wittik, F. Wich; Studio + Sim. Prof.: Author*

Björn Wittik's and Franziska Wich's design for Östersund, Sweden (Köppen climate class. Dfc), was created in the "Performative Design" class cycle, which dealt with energy-efficient (sub)urban housing typologies; both urban layouts and modular housing types were developed and tested in their interplay, which is challenging due to unit overshadowing and the influence of housing layout on what can or cannot be achieved on an urban level. After the first class iteration, both students enrolled in the spatial mapping class to gain an even greater understanding of how their design performed.

Their overall workflow followed a rough staging regime:

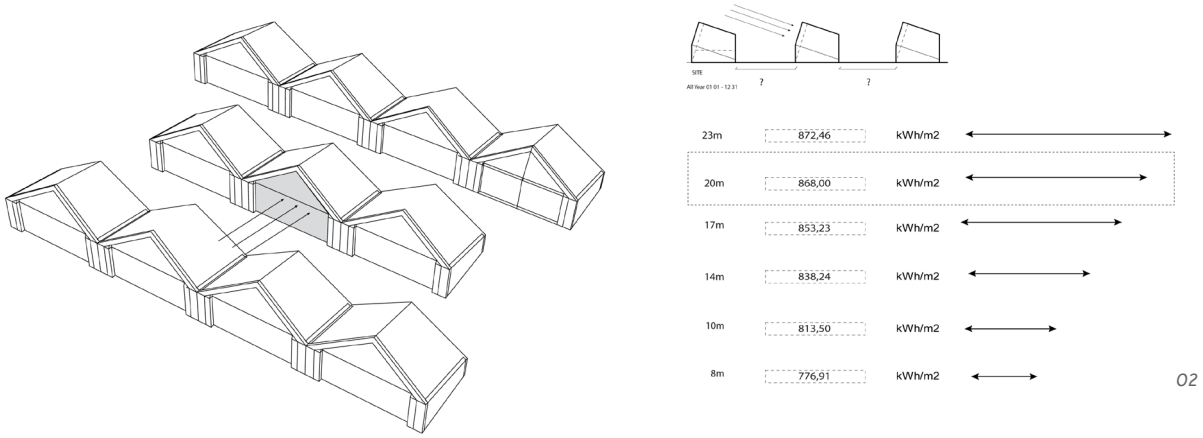
- Create locally inspired minimalist housing design language
- Develop conceptual passive conditioning idea (sunspace)
- Test housing unit overshadowing & facade irradiance
- Detailed performance mapping & house typology modifications

However, the actual design process included many subvariants, experimental changes, failures, errors, recovery and renewed understanding through experiencing the above; the narrative presented here is retrospectively condensed for clarity.

The spatial language of the development is inspired by contemporary Nordic housing design and vernacular typologies. Östersund's subarctic climate (Köppen class Dfc) requires the capture of solar gains for passive conditioning, therefore a south facade tilt and relatively large row spacing of the houses, which sit shoulder to shoulder to reduce fabric losses, were chosen and tested through irradiation simulations (right).

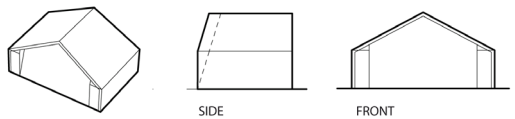
*Opposite:*
*01 Design Development Phasing, Final Iteration Site Plan*
*02 Row Housing Overshadowing Distance Study*
*03 Combined Overshadowing + Facade Tilt Irradiation Studies*


01




02

Variante 05




south facade tilted at 20° angle
(orthogonal to yearly average sun angle)
overhang cut back

solar irradiation south facade:

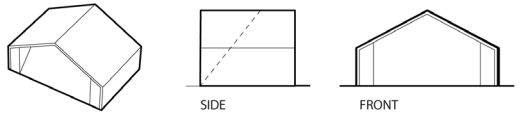
Summer 04 01 - 09 31

AVERAGE: 641,30 kWh/m2

Winter 10 01 - 03 31

AVERAGE: 168,00 kWh/m2

Variante 02




south facade tilted at 47° angle
(orthogonal to summer average sun angle)

solar irradiation south facade:

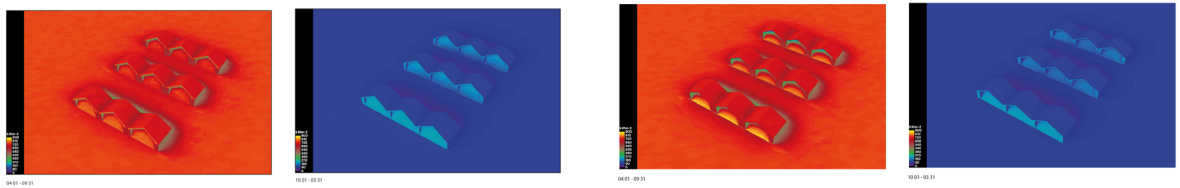
Summer 04 01 - 09 31

AVERAGE: 430,27 kWh/m2

Winter 10 01 - 03 31

AVERAGE: 180,40 kWh/m2

03



# SPACE-BASED THERMAL METRICS VISUALIZATION

*p. 48 | Sweden Urban Housing Design Optimization*
*Design: B. Wittik, F. Wich; Studio + Sim. Prof.: Author*

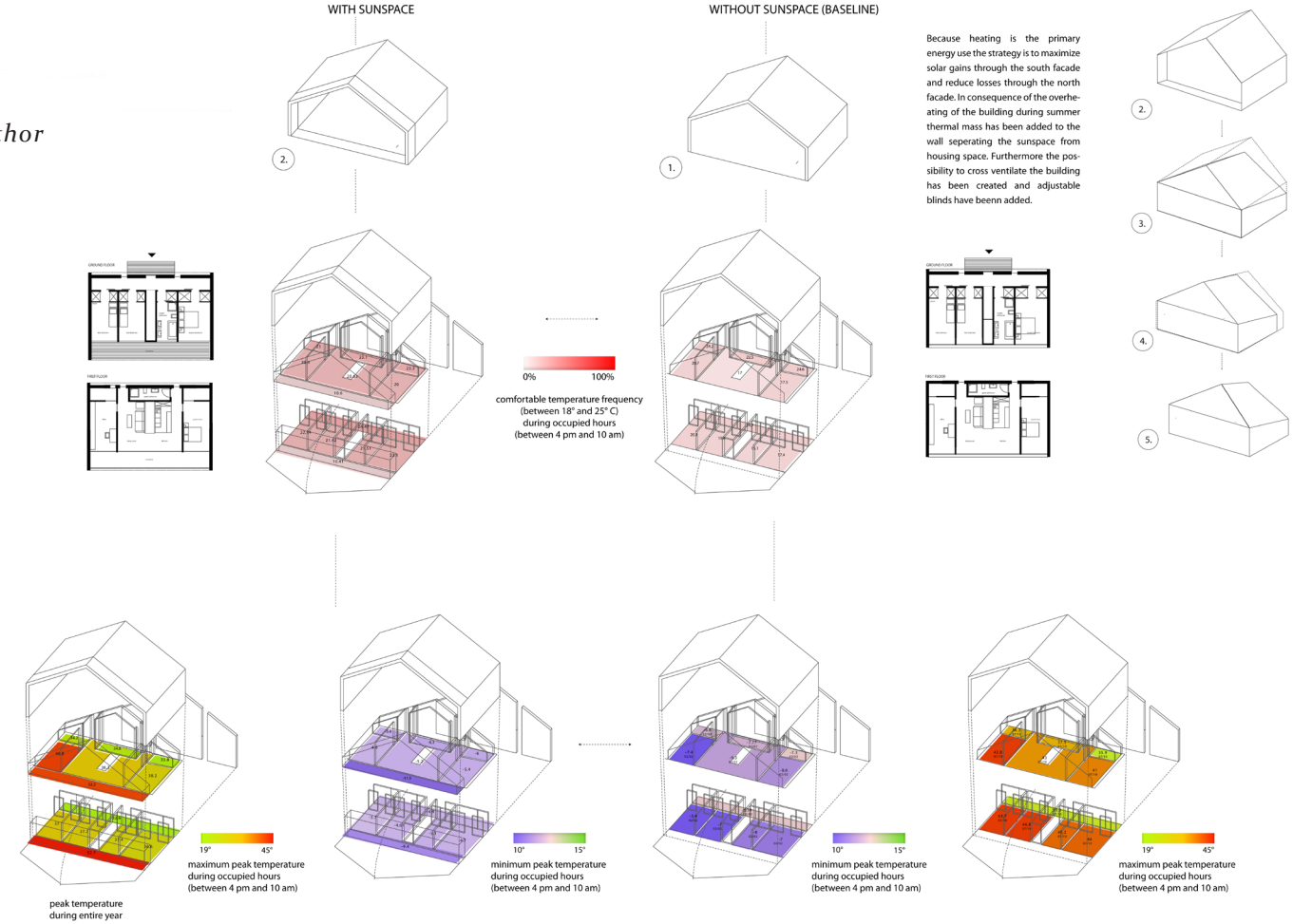
The overall unit development was staged and always seen in relation to the overall urban scheme:

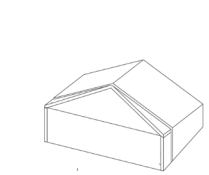
- Test sunspace vs. no sunspace performance
- Reduce north facade areas by tilting units
- Minimize unit size to improve surface/vol. ratio
- Tilt upper south facade to increase gains
- Balance seasonal behaviour (glazing area, shading)

The impact of building fabric changes was generally measured with the simplified metric zone air temperature; this limited approach gave students an "intuitive" metric to work with, compared to comfort indices sensitive to different variables and not always usable in unconditioned buildings, as the test geometries generally were.

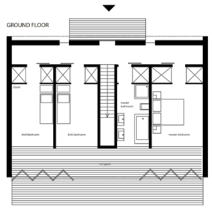
In the first step (right), students through frequency and peak mapping compared unit performance with and without sunspaces; the former was found to be preferable, with a measurable increase of hours held in an acceptable air temperature range of 18 - 25°C and a reduction in severity of both minimum and maximum hourly air temperature peaks- albeit both remained severe.

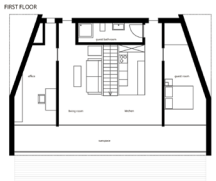
Based on the tests, the sunspace typology was selected and further developed to balance seasonal performance.

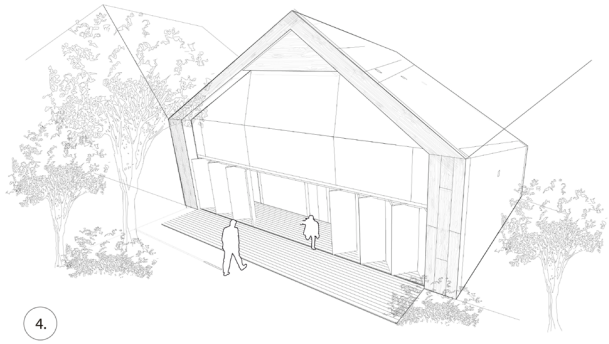


DESIGN WITH SUNSPACE,
TILTED ROOF / SOUTH FACADE



4.

*Opposite:*
*Peak, Frequency Mapping Comparison of Base Design State with and without Sunspace, Unconditioned Version Floor Plans,*
*Conceptual Rendering (lower right)*

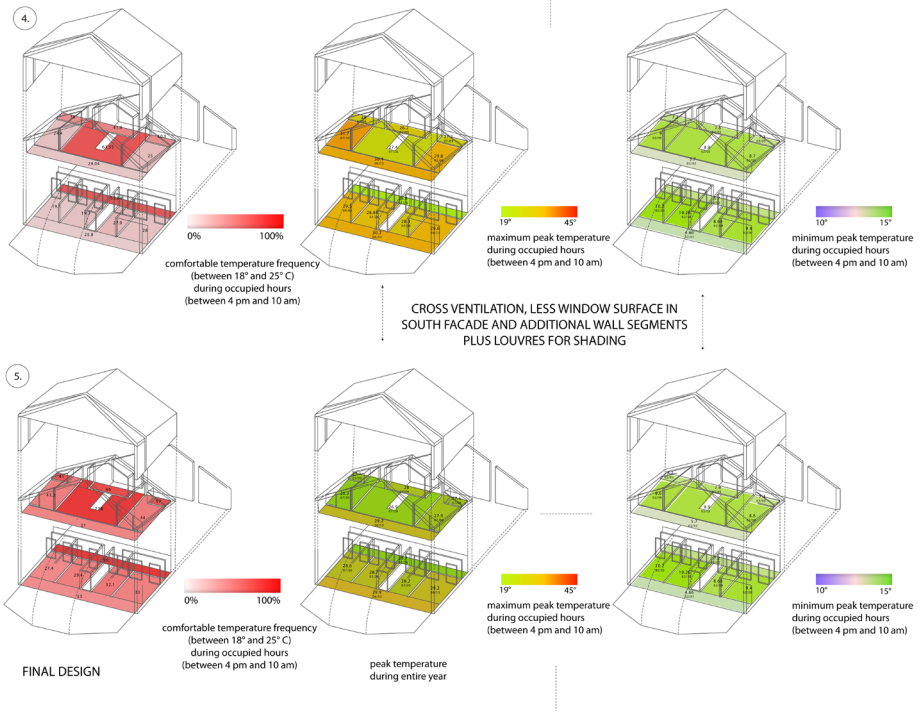
# SPACE-BASED THERMAL METRICS VISUALIZATION

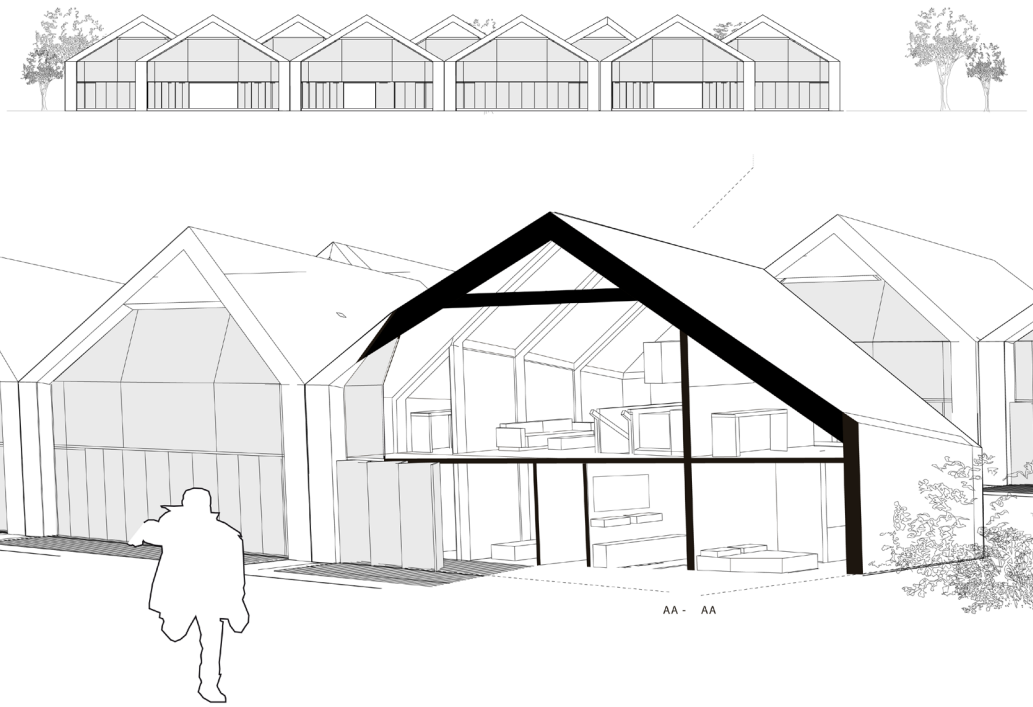
*p. 49 | Sweden Urban Housing Design Optimization*
*Design: B. Wittik, F. Wich; Studio + Sim. Prof.: Author*

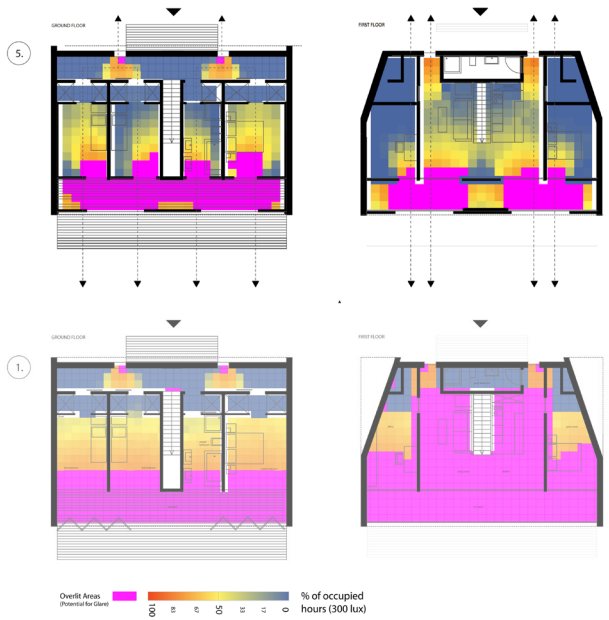
Capturing solar gains can come with a penalty during summer; in the chosen design, overheating turned out to be an issue difficult to rectify with e.g. mere fixed overhangs due to low solar angles; correspondingly, extreme daylight overprovision also occurred.

To gain a degree of control over summer behaviour (and incidentally also reduce winter losses), students increased the outer and inner sunspace opaque mass wall area and allowed shading plus sunspace/all-house cross-ventilation, triggered by high zone air temperatures. Maxima peaks and frequency readings were improved greatly (right), as was daylight utilization, which finally exhibited fewer overlit hours.

*Opposite: Final Design State with vs. without Shading + Natural Ventilation Comparison, Unconditioned*
*Bottom Right: Final vs. Base State Daylight Availability Comparison, No Shading*
*Below: Conceptual Sectional Rendering + Elevation, Pre-final Design State*



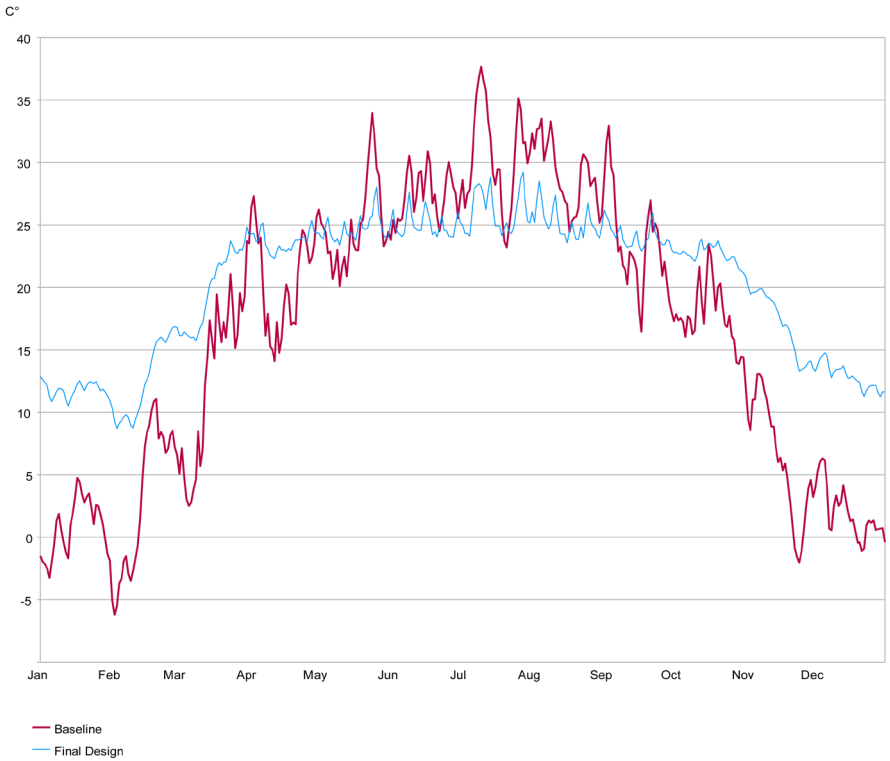
# SPACE-BASED THERMAL METRICS VISUALIZATION

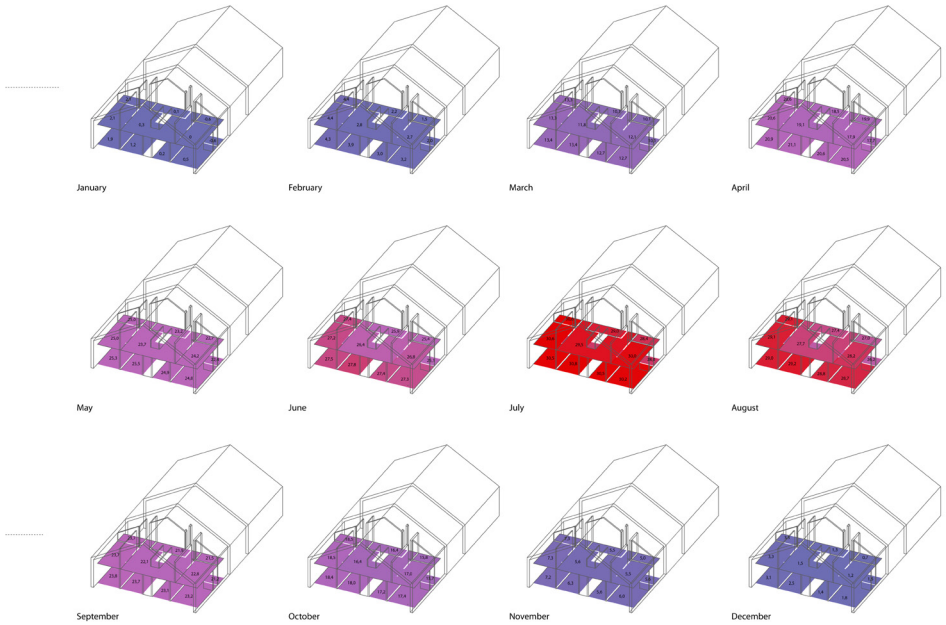
*p. 50 | Sweden Urban Housing Design Optimization*
*Design: B. Wittik, F. Wich; Studio + Sim. Prof.: Author*

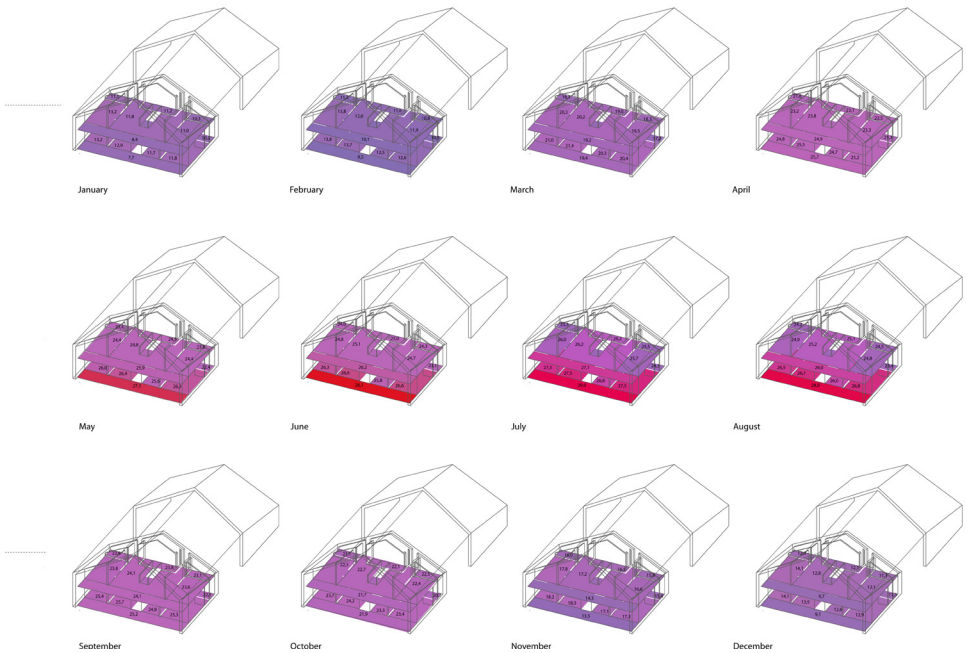
Comparing the base state and final design iteration average monthly air temperatures through seasonal maps (right) and a traditional line chart (below), the modification effects already visible in the previous peak and frequency readings become more readable in their temporal localization. Both minima and maxima peaks are reduced; however it remains visible that problems with overheating in summer months continue to persist.

The class terminated at this improvement milestone, however it was clear to both students and me that more work would be necessary to bring down air temperatures to an even greater acceptability level, and in the process to investigate detailed comfort metrics.

*Opposite: Base (top) vs. Final (below) Monthly Average Zone Air Temperatures, Unconditioned*
*Bottom: Base vs. Final Design State Daily Whole-Building Average Air Temperatures, Unconditioned*





during occupied hours
(between 4 pm and 10 am)

# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 51 | Design-Driven Performance Simulation*

- Series of 7 simulation-integrated design classes (incl. studio)
- Building performance cognition and design process research
- Publications: e.g. Building Simulation 2013, eCAADe 2012, etc.

From 2011 to early 2014, colleagues and I at the TU Berlin researched the integration of dynamic daylight (Daysim + Radiance) and thermal (EnergyPlus) building performance simulation into freely structured design processes. Four different class formats with more than 100 MArch. students served as test environments, dealing with the low-energy design of office buildings, community centers, housing with its interplay of individual units and urban layout, as well as spatial performance mapping with custom developed software (Mr.Comfy). In each class, typologies were created for several climate zones and mainly geometric sensitivity tests performed, leading to building morphologies that reacted to specific climatic conditions.

The successfully completed project had three main goals:

- Investigate integrated design + simulation process formats
- Research morphological impact on building performance
- Develop cognition/simulation support tools to facilitate integration

From design + simulation activities, emprical observations were made and developed into a dynamic integrated design/simulation process model, which was used to create performance design guidelines in new classes and to develop custom spatial analysis software to enhance free-form performance ideation and analysis.

Results were published widely, most notably at Building Simulation 2013 at the French Institut Nationale d'Énergie Solaire and at DIVA Day 2013. See http://mrcomfy.org/?page_id=116

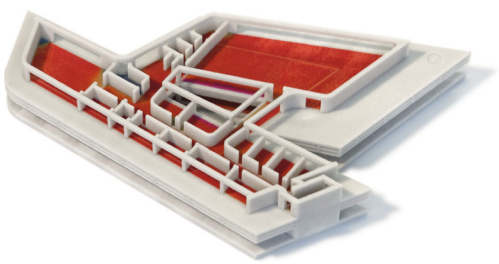
*Background/Opposite:*
*Students R. Georgieva + C. Castillo presenting class designs + simulations*
*Parametric Design Class, Winter 2011/2012*

# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 52 | Class Types Overview 2011 - 2014*

## A : Parametric Design [Climates : 1, 2, 4]

*Community Center & Offices*
*(mechanically conditioned)*

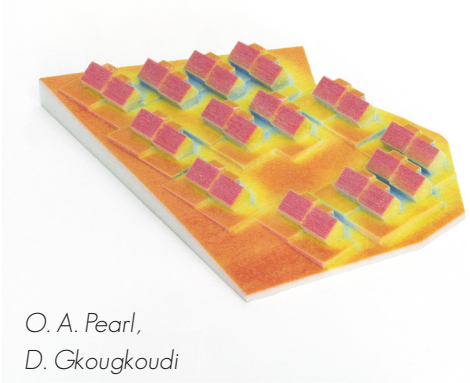


*R. Canihuante,*
*M. El-Soudani*
*Office Bldg. (FL site)*

*Strategies:*
*Geometric optimizations*
*Fixed materials & setpoints*
*Balance thermal & daylight*

## B : Performative Design [1, 3, 4]

*Housing Units & Urban Design*
*(passive & mechanical conditioning)*

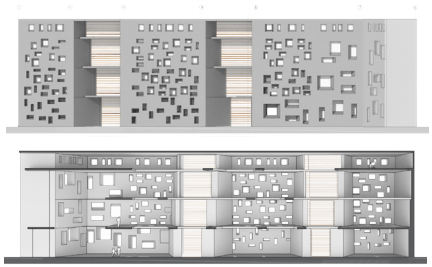


*O. A. Pearl,*
*D. Gkougkoudi*
*Housing units (SWE site)*

*Geometric & material optimization*
*Fixed setpoints & U-Val., custom mat.*
*Thermal performance focus*

## C : 'Robust' Studio Integration [5]

*Multi - Use Exhibition & Office building*
*(mechanically conditioned)*

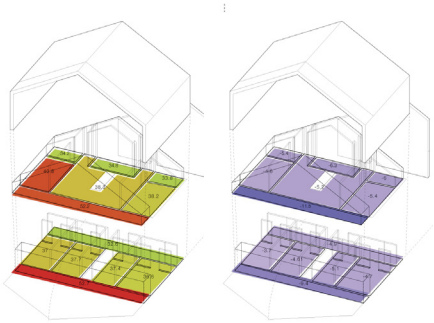


*B. Suazo, M. Silva*
*Mixed-Use Exhibition Building (Berlin site)*

*Geometric & material optimization*
*Custom setpoints, mat. & behavior*
*Individualized performance tests*

## D : Performance Mapping [1 - 5]

*Spatial Thermal Performance Visualization*
*+ Optimization with Custom Software*



*F. Wich, B. Wittik*
*Housing Development (SWE site)*

*Comfort and energy use behaviour discovery & optimization visualization of new and previous class designs*

## Design Climate Zones

*1 Hollywod, FL, USA*
*Climate.: Am (Köppen class)*

*2 Hashtgerd, Iran*
*Climate: BSk*

*3 Yazd, Iran*
*Climate: BWk*

*4 Östersund, Sweden*
*Climate: Dfc*

*5 Berlin, Germany*
*Climate: Dfb*

# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

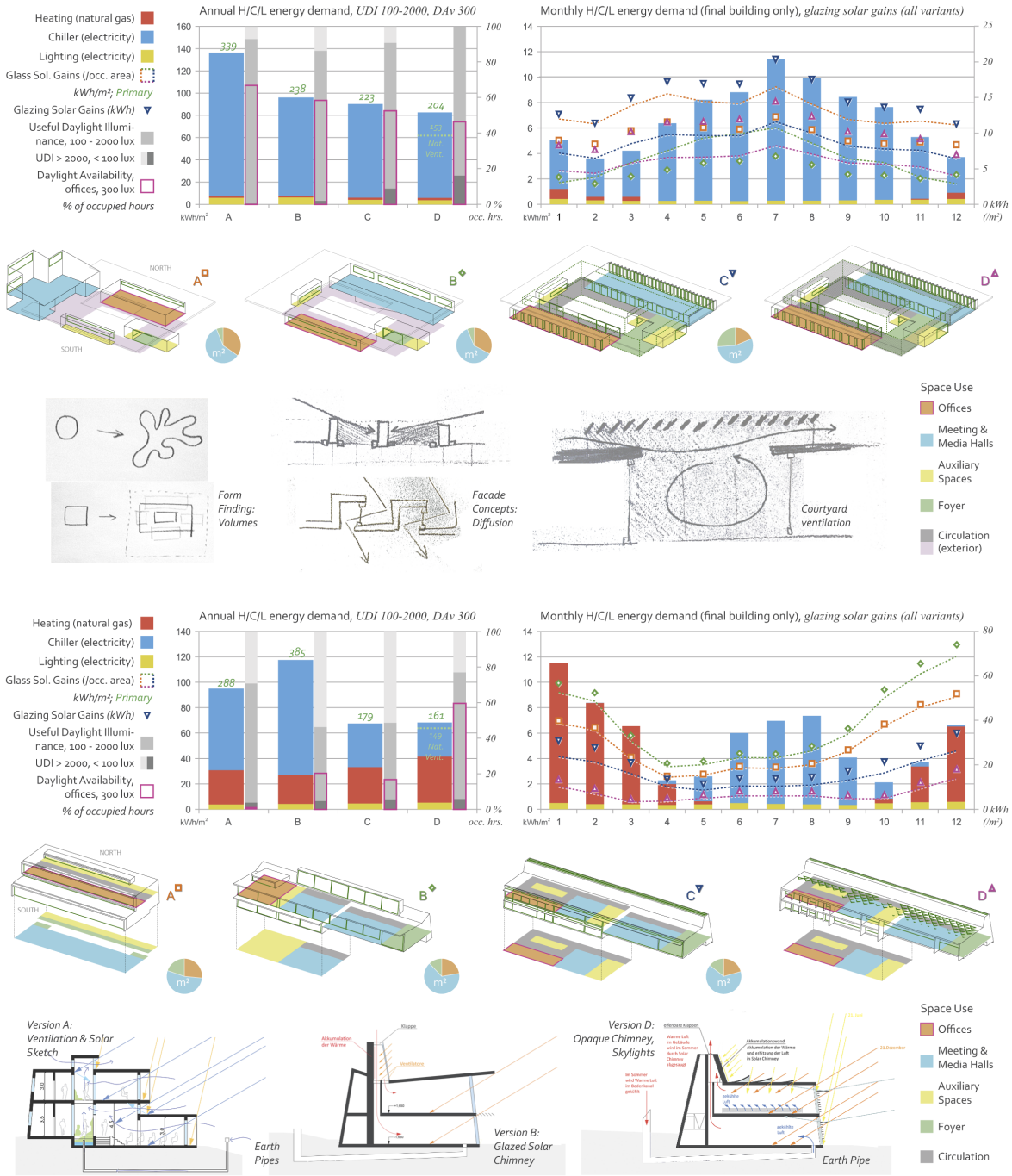
*p. 53 | Combined Design + Performance Development*

Performance intent is often not an integral part of design processes, despite the early ideation stage's fundamental influence on later energy use and occupant comfort. To counteract this disconnect, the interplay of form and performance was in our classes studied in great detail, primarily to develop a new process model and to test the conceptual use of whole-building simulation. The graphics to the right chart the combined performance and design development of two buildings of the same programme, but for different climate zones (Ft. Lauderdale, Florida, top; Hashtgerd, Iran, bottom); optimization is not linear but steadily progresses in unison with architectural decisions. As summarized in the abstract for my Building Simulation 2013 paper:

"[...] With initiatives now aiming at bringing energy simulation into the mainstream of environmental design, the applicability of state-of-the-art simulations in formally non-constrained creative production needs to be re-evaluated. To this end, a teaching experiment that includes multi-domain simulations as drivers into the early architectural design process has been conducted; Master of Architecture students create a community centre with low energy use and high daylight utilization, presented in case studies. Performance increases are achieved by making appropriate morphological choices only; form and energy are thus linked in a tectonic fashion. A novel design-simulation process model that acknowledges both creative and analytic thinking is derived and discussed in the context of on-going integration attempts."

The developed integration model was also tested in advanced architectural design studios such as 'Robust' (see following).

*Opposite: Combined Daylight + Thermal Building Performance Design Development Community Center, Ft. Lauderdale, FL, USA (top) + Hashtgerd, Iran (bottom) Students: I. Crego, D. Cepeda + T. Merickova, M. Potrzeba, Parametric Design Class Studio, Simulation Prof., Simulation Validation + Performance Graphics: Author*



# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

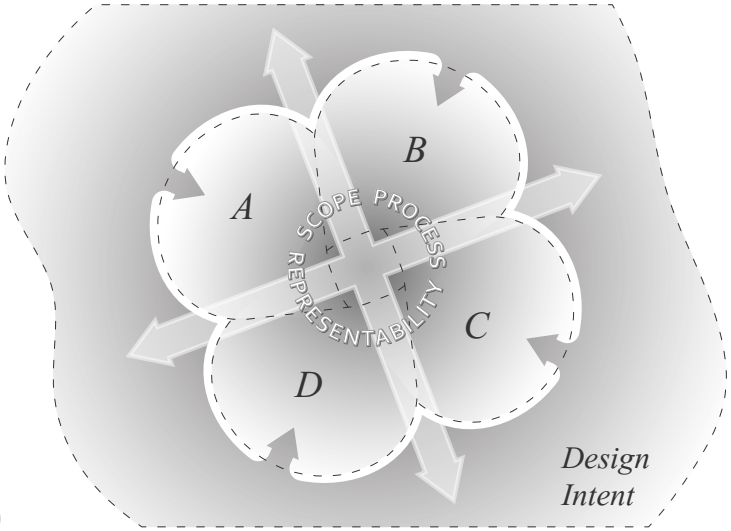
*p. 54 | Integrated Process Model Development*

Integrated workflows in architectural design are amongst many factors dependent on individual project idiosyncrasies, climate influences and learned process histories. In pursuit of capturing these dependencies, a large body of building simulation literature attempts to identify "ideal" workflows; yet the now greater diffusion of simulation into academic and professional design has invalidated many simplified and purely iterative process models, as they fail to capture the non-linear nature of design thinking- as also apparent from the discussed class examples and their ideation history.

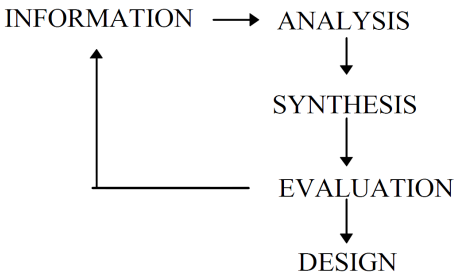
Shown on this page are several snapshots of how the development of integration thinking has progressed, including a novel model by the author (top right, description see inset text, right). It is by now accepted that high-performance building design is a discipline in its own right, with the influence of architectural thinking on its concepts no longer underemphasized. The model is used by the author to improve pedagogy and to test if new design support technologies, such as spatial thermal metrics mapping also discussed in this portfolio, fit into fluid design process schemes.

"An integrated process is a dynamic field of related design states and should not be represented linearly."

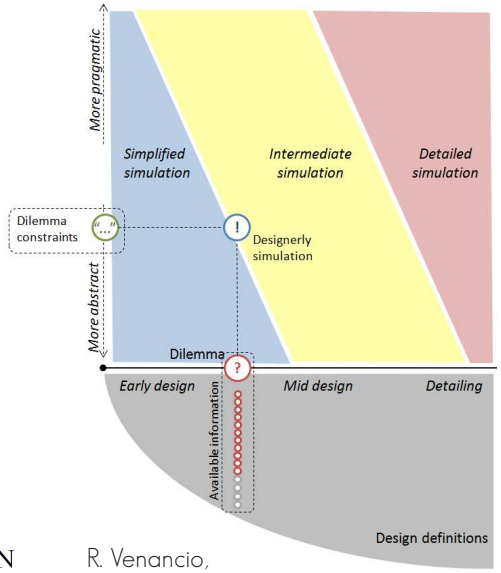
M. C. Doelling & F. Nasrollahi
Dynamic Field Design/Simulation Process Integration Model
(Building Simulation'13)




"The basic procedures involved in the design of a commodity are the same whether it be a toaster, supersonic passenger aircraft or a building."




W. J. Batty & B. Swann: Integration of Computer Based Modelling and an Inter-Disciplinary Based Approach to Building Design [...], (Building Simulation '97)

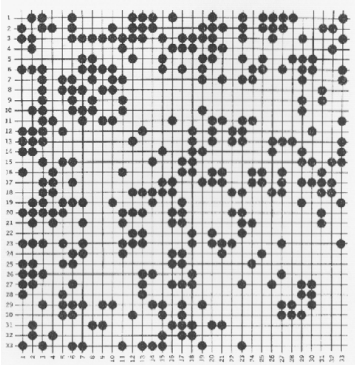



R. Venancio, A. Pedrini, A.C. van der Linden, E. van den Ham & R. Stouffs: Think Designerly! Using Multiple Simulation Tools to Solve Architectural Dilemmas, (Building Simulation '11)

"The focus of simulation is to solve design dilemmas. [...]

The identification of three main design stages is not neccessarily a reproduction of the [design] process. " (Venancio et al.)

Chermayeff & Alexander ('63): Design Factor Interdependencies



*Integrated Design Process Model, Development Context*

*Most notably, Chermayeff and Alexander already described in 1963 that design is a wicked problem with myriad interdependencies (pictured) that do not allow for truly linear or iterative processes to develop.*

*Experiments in integrated class formats held during the author's research project reaffirmed this and led to the development of an adapted field process model (above), which accepts design as a non-linear, explorative activity that chiefly relies on the interplay of mutually influential knowledge states from related domains.*

*In the model, design intent encapsulates all knowledge domains (A, B etc.), which are mutually influential, create design synthesis through overlapping decision states and subsequently modify design intent, for the entire process to begin anew until it is frozen at a satisfactory moment or all domains are exhausted in their contribution potential.*

# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 55 | 'ROBUST' Interdisciplinary Studio*

Building on previous experiences, the author and colleagues in summer 2013 participated in an interdisciplinary MArch studio held by the department of Prof. R. Leibinger. The theme "robust" underpinned the investigation of flexible structures built out of modular, high-volume spatial elements. The program brief, adapted from the 2013 Egon Eiermann competition requirements, called for multi-use exhibition, event and administration spaces; the downtown Berlin site chosen in consultation with the author was elongated along an east-west axis and opened the main facade stretch towards the south, easing seasonal performance optimization in Berlin's heating-dominated climate.

Students performed design-centric daylight (Daysim + Radiance) and thermal (EnergyPlus) performance simulations in class, which were introduced and guided by the author and colleagues, who also acted as design/performance consultants. The simulation scope was unique per project, however performance assessments played a major part in shaping design decisions, following a fluid didactic and design-centric process model.

Demonstrating the quality of the resultant designs, the first prize of the 2013 Egon Eiermann competition was claimed by 'ROBUST' studio students (right). Its main design/performance interplay was to analyze facade versions, resulting in a double-walled glass facade with interior louvers adjusted according to thermal simulations, irradiation and daylight studies.

Two successful studio results are shown next; the first used simulations to shape a design with various zones of daylight contrast while minimizing heating energy use; the second studied deep facade geometries to control seasonal irradiation, related energy use and natural light. Both designs were further optimized in the performance mapping class also found in this portfolio.

1st Prize **1. PREIS**

**Robust**

**Reiner Beelitz | Lubomir Peytchev**

Technische Universität Berlin,
Lehrstuhl für Baukonstruktion und Entwerfen

Design Chair: Prof. Regine Leibinger

Studio Leaders: Betreuung: Dipl.-Ing. Mathias Graf von Ballestrem, Dipl.-Ing. Jan-Oliver Kunze, Dipl.-Ing. Bogdan Stugar

Coop.: Structural Design: in Zusammenarbeit mit dem Lehrstuhl für Tragwerkslehre und -konstruktion, Prof. Klaus Rückert
Betreuung: Dipl.-Ing. Jan Grunwald

Coop.: Author: und Digital Processing for Academics unter der Leitung von Dipl.-Ing. Max Dölling

16
17

Atrium Atrium

Ausstellungsraum Exhibition

Raumprogramm Programme

Rotation der Lichtschutzlamellen Sol. Protection

Erdgeschoss und 1. OG
1st / 2nd floor

Schnitte und Ansicht von Osten East Section + Elev.

Reiner Beelitz wurde 1986 in Neuruppin geboren. 2007 begann er sein Architekturstudium an der TU Berlin, das er 2014 mit einem Master abschließen will. 2012/2013 Auslandssemester an der TU Delft.

Lubomir Peytchev, 1980 in Sofia geboren, studierte zunächst Jura ehe er 2007 sein Architekturstudium an der TU Berlin aufnahm (Bachelor 2011). 2011/2012 Auslandsjahr an der TU Delft (Masterprogramm).

*1st Prize Winner of Egon Eiermann Architectural Competition 2013*

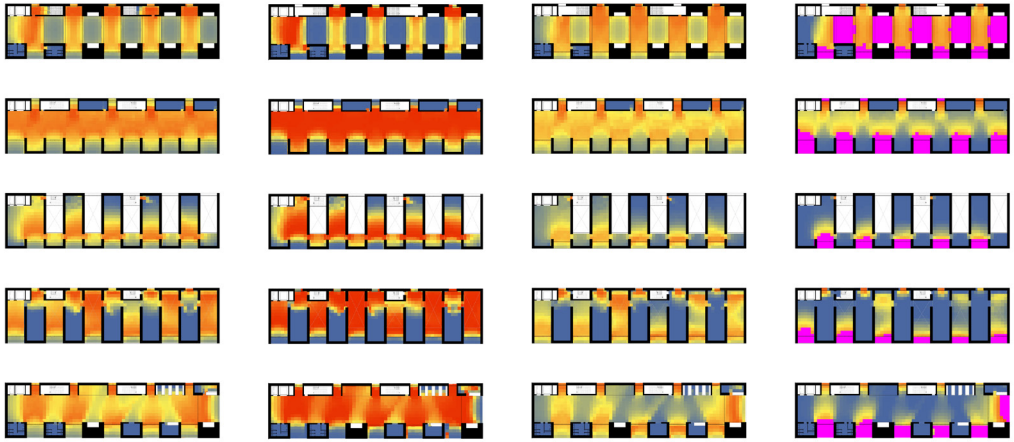
*Translation of jury verdict: "The work's great quality results from extending the concept of 'Smart Skin' [competition theme] to become a holistic system that shapes space. The light concrete pillars' contribution to thermal performance is believingly described and construction concepts that allow geometric variability are investigated in detail. The interplay of transparent facade and climatically active pillars creates a convincing, flexible and powerful space".*

*Source & image credits: Eternit AG. Egon Eiermann Preis 2013: Smart Skin, ein Haus der Materialforschung. Stuttgart: Karl Krämer Verlag, 2013.*

# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 56 | 'ROBUST' Studio Class Result Sample*
*Design: C. Sitzler, L. de Pedro; Sim. Prof.: Author*

(Seasonal) UDI 100 - 2000 lux & DAv 500 lux daylight studies for alternating interior contrast situations



UDI 100 - 2000 Lux | UDI 100 - 2k (summer) | UDI 100 - 2k (winter) | D. Availability 500 Lux

04 Research, Administration

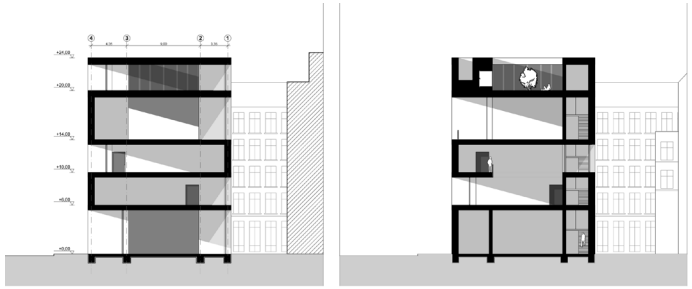
03 Multi-Purpose

02 Exhibition

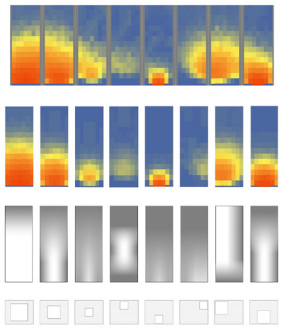
01 Exhibition

00 Events

Cross Sections

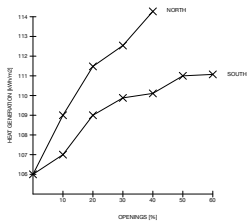


Lateral Section

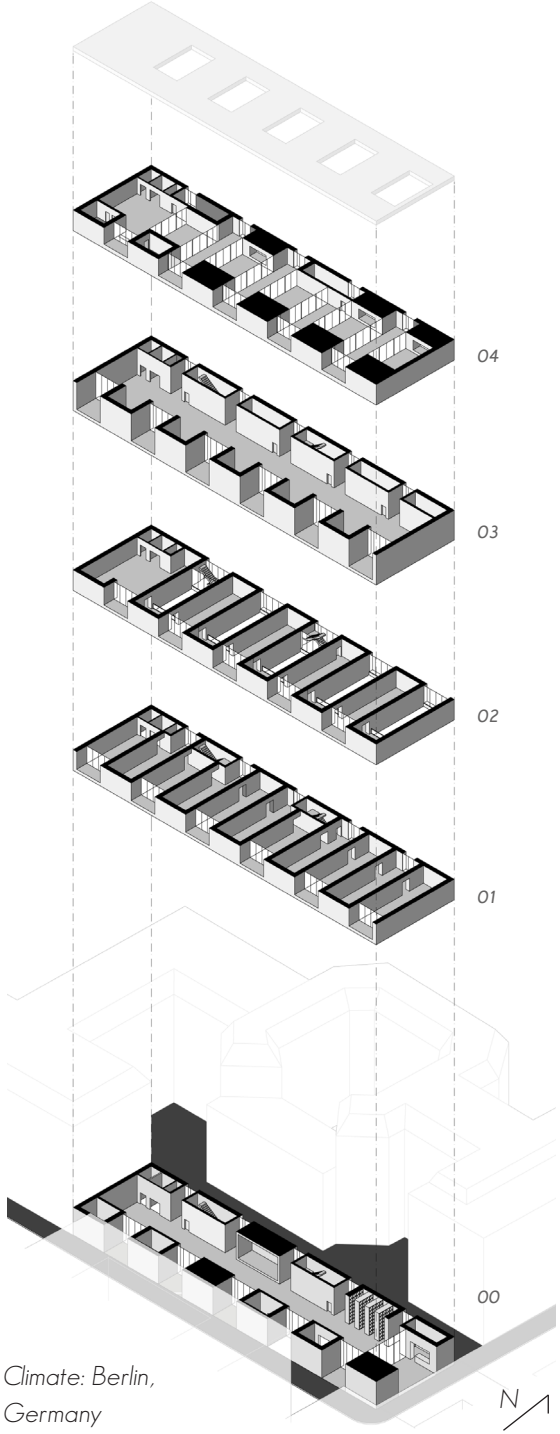


100% occ. hrs. 0%

Intended interior daylight volumetrics (greyscale) vs. simulation results



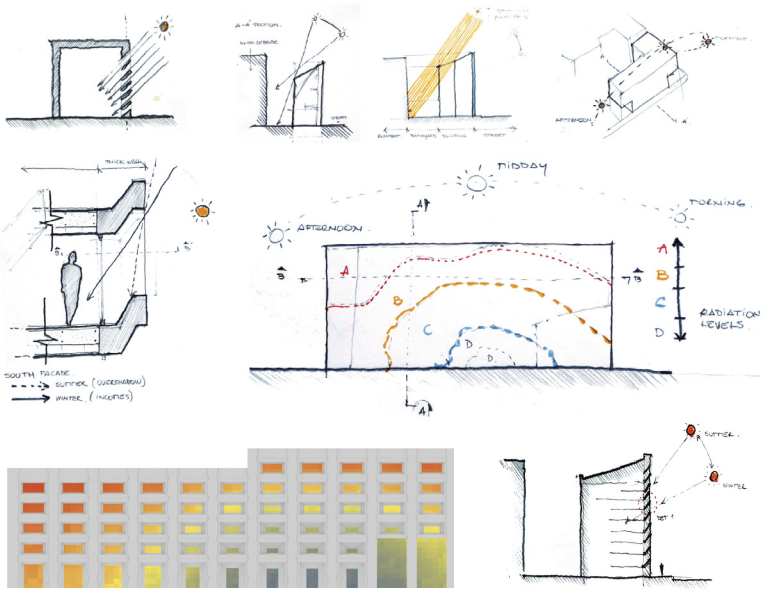

Window to wall ratio effect on heating energy use studies




Climate: Berlin, Germany

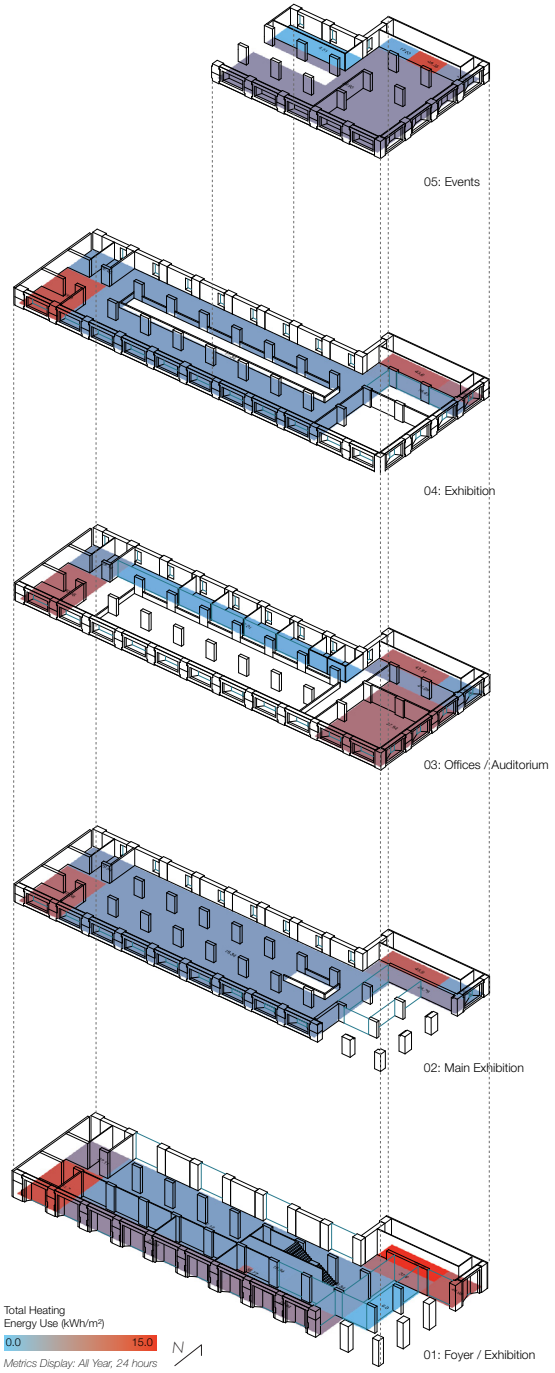
# PARAMETRIC DESIGN: A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 57 | 'ROBUST' Studio + Performance Mapping Results*
*Design: A. Patrick, P. Cárdenas; Sim. Prof.: Author*

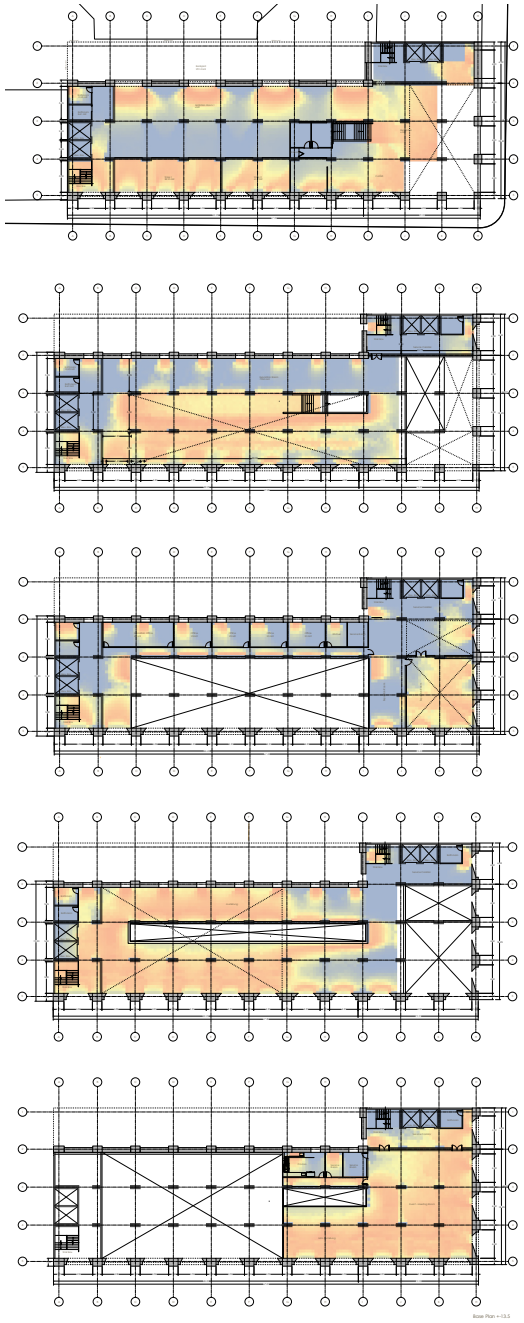



*Performance Sketches + Annual Irradiation Distribution on Elevation*

*Main View of South Facade*




*Thermal Reoptimization Map (from followup class)*



*Daylight Availability, 500 lux* 0% occ. hrs. 100%

PARAMETRIC DESIGN:
A CASE STUDY IN DESIGN - SIMULATION INTEGRATION

*p. 58 | A. Patrick + I. Cardenas presenting, final crit of 'ROBUST' Studio*

## Student testimonial

To whom it may concern.

My name is Piotr Jardzioch and I attended the courses organized by Max Dölling during my master studies at the Technical University of Berlin.

I value Max's professional knowledge very much. Connecting not only the architectural design with energy optimization, but far more with the application of specialized software for simulations of building energy consumption, he provided us the tools for implementing new concepts into the architectural design. He perfectly managed to present the complexity of this parametrized approach through the variation of the climate zones used in the course.

The time I spent learning about climate responsive architecture was one of the best experiences of my studies. The clear, structured way in which Max presented the goals enabled a very efficient workflow. Presenting big context at the beginning and focusing on the most complex issues at the end, Max has never lost contact with the students and has proven being very patient with our questions. Even interrupted, he would always find his way back to the topic. Max contributed during countless consultations in a very special way to the evolution of the initial ideas, always encouraging and targeting our efforts in the most promising direction.

In comparison to the other classes I have been attending, this course enhanced my skills and abilities in the most durable way. From this time on I started using new methods in my architectural work. That is why I could hardly overestimate the impact this extraordinary experience has made on my architectural education. More over I would like to express my great gratitude for all the work Max put into the preparation and implementation of the courses. He has been excellent both in professional and didactic aspects and opened new ways of creating architecture for me.

Jardzioch

Piotr Jardzioch M. Sc.

Berlin, 12.02.2014

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eloy@grupocactus.cl

## Letter of recommendation

To whom it may concern,

during the whole academic period of my architecture student life, I was always very attracted to two specific branches of the discipline: Parametric design and sustainability. Mostly, both branches are always seen independently, which makes these knowledge areas incomplete and hollow: parametric design was just an architecture stream defined by curved surface and complex organic forms where the main target was to achieve an impact sculpture type of architecture, and the sustainability architecture was reduced to construct with bottles.

During the academic summer term of 2011 in Berlin as a double degree program student, I got into a class which broke all these preconceptions. Parametric Design's aim was, for first time in my academic life, not to achieve forms, but to achieve efficiency. The inputs where not geometrical, but energy efficiency related. The output was not a sculptural cool shape, but the optimized geometry instead. Of course, this didn't happened by itself, and Max Dölling had the major responsibility of it.

It was not just the technical knowledge (which solved an issue in a couple of minutes because of understanding a problem from the root) that made him the main character of this successful class, but also his architectural understanding of the problematic involved in each of the studied cases, which always brought out solutions full of architecture and spatial features. This is a very important point, since in lots of classes related to sustainability are presented by engineers who isolate these variables, which gives architecture its particularity.

I would recommend Max to any class related to Parametric Design and energy efficiency concepts, or even a workshop, that with no doubt would have visionary projects as results.

Eloy Bahamondes E.
Architect

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**Course Experience Testimonial "Performative Design", TU Berlin**

I participated in the course "Performative Design" in the winter semester 2012/13. The course was led by lecturer Max Dölling.

During the course students learned to design housing typologies that are adapted to their climatic context. Three types of buildings were developed where one was in a desert climate, one in a subarctic continental climate and one in the subtropics. Programs like DIVA, a daylight simulation plug in for Rhinoceros, DesignBuilder for energy simulation and Climate Consultant helped us to develop our design ideas dependent on human comfort needs.

Max made a real effort to give us an introduction into all programs we needed for the course. During weekly tutorials providing program skills we were able to ask questions and discuss problems to which the lecturer gave us helpful feedback. At the end of each class we received one week tasks that we presented in the next lesson. Max put a lot of time into evaluating this work.

He communicated the course content effectively and he was extremely good in explaining things. This showed that he worked hard to make the course interesting and that motivated me to do my best work. In the end our design outcomes were printed with a 3d printer and our research achievements are to be included in a MIT book. The course's up-to-dateness and respectability were remarkable.

The climate of the course was very satisfying. I found Max's approach to intellectual and complex topics very pleasant, which he communicated with a lot of humour. This approach made even a complex topic appear easygoing. His effervescent character was very motivating. His goals and expectations were clear until the end, and we learned many specific skills with programs like Rhinoceros, Grasshopper, Diva and DesignBuilder. The workload was always appropriate.

All in all I was very satisfied with the course. To participate was important for me because it will be relevant for my future work. Parametric design with the use of climate data becomes more and more important. The integration and calculation of climatic performance for each building seems to be complex right now, but I find that it needs to become the foundation and a basic principle the design process should rely on, and that can only be achieved if courses like this are further offered by universities. I believe that this course is indispensable for sustainable design.

Anastasiya Vitusevych , Berlin den 13.01.2014

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Higher School of Architecture
University of Seville, Spain

To whom it may concern:

I was Max Dölling's student in "Parametric Design" at the TU Berlin, Germany, in the winter term of 2011/12 and I can responsibly affirm that he was a trained, committed and a dedicated professor.

He had a good performance as professor, standing out extraordinary skills in performing ideas and explaining them in different languages, the interesting content of his lessons, his mathematical, architectural and informatics knowledges and his upbeat character and good disposition to work make him a valuable team player.

In addition, he has an interesting curriculum as researcher and he could include our design investigations in several international publications of design and simulation seminars, one of which was presented at the Massachusetts Institute of Technology, Cambridge, MA, USA.

I recommend very strongly Max Dölling as researcher and professor, as he has demonstrated an excellent analytical ability and capacity to grasp and explain new concepts necessary for success. His motivation and passion for his work, together with his intellectual capacity are the perfect combination to achieve excellent results.

I also believe he would be a good candidate for a vacancy, as he would go the extra mile to deliver his best performance and honour the institution that gives him that chance.

Yours faithfully,

Architect - David Cepeda del Toro
Seville, 16th January, 2014

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# HYBRID DAYLIGHT MODELS IN ARCH. DESIGN EDUCATION + DAYLIGHT PROTOTYPES

*p. 61 | Data-Embedded Physical Performance Models*

- Hybrid design + performance representation research
- 3d printing of novel color-embedded iteration prototypes
- Publications: e.g. CAADRIA 2013, DIVA Day 2012, etc.

As one component of the research into design-integrated daylight and thermal building performance simulation performed during my tenure at the TU Berlin, I made extensive use of rapid prototyping techniques to output design performance artefacts such as the daylight and irradiation models shown on the next pages, resulting from a series of simulation studios.

Models play a vital role in architectural design, but it is not always easy to reconcile projective on-screen representations of simulation data with model-centric modes of design manipulation.

The artefacts created by students under my guidance thus presented tests into how irradiation, daylight data and even thermal performance can be physically output as color-coded models easy to understand and to literally grasp, with the ultimate aim to enhance design processes. This was achieved by using the models as demonstrator objects in new classes and through them discussing performance design aspects in ongoing seminars.

The models were featured in several project publications, most notably at MIT for my 2012 DIVA Day presentation and in 2013 at the CAADRIA conference at the National University of Singapore.

See http://mrcomfy.org/?page_id=116 to access them.

*Background/Opposite:*
*UDI 100 - 2000 lux Daylight Metric-Embedded, Physically Rapid-Prototyped Daylight Model, disassembled. Design: T. Merickova, M. Potrzeba Studio, Simulation Prof. + Prototyping: Author*

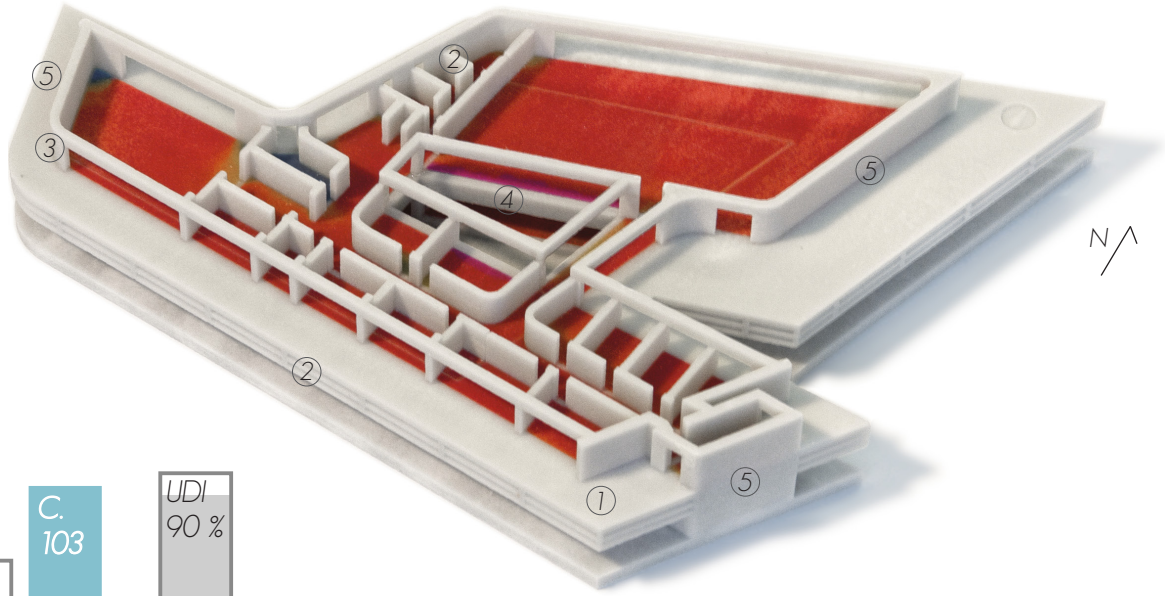
# HYBRID DAYLIGHT MODELS IN ARCH. DESIGN EDUCATION + DAYLIGHT PROTOTYPES

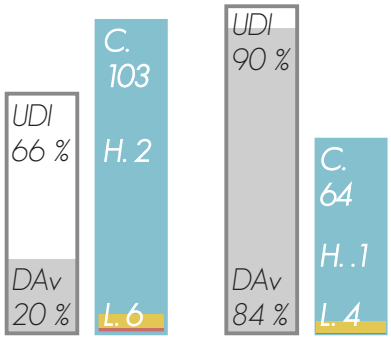
*p. 62 | Office Building + Community Center Performance Studio, Simulation Prof. + Prototyping: Author*

Good climate-based daylight and thermal performance tend to be correlated in many different climate zones. The major model type produced in our studios therefore were disassemblable daylight models that capture a design's physical layout and how it affects all-year daylight performance of the final design state, with intermediate artefacts printed during the ideation process.

The right-hand image shows an conceptual office building design for the climate of Ft. Lauderdale, South Florida. It is the model of the final design variant, with the design performance of the first iteration shown in contrast. The daylight metrics UDI 100 - 2000 for general spaces and Daylight Availability at 300 lux for office spaces are included to show a fine-grained appreciation for different daylight demands; both UDI and DAv are above 80%, which is a good result. Cooling energy use was reduced by a projected 39 kWh/m², which considering Florida's tendency to penalize higher daylight utilization through increased cooling demand is astonishing. The result was achieved through careful shading design and changes in the original design's morphology.

The bottom strip of images shows related buildings from the same and alternate climate zones: Florida, Iran (Hashtgerd), Sweden (Östersund) and once more Iran, all of which exhibited similar performance increases through smart geometric design choices. All facing facades are oriented South.




*Initial Variant*
*275 kWh/m²*

*Final Variant*
*170 kWh/m²*

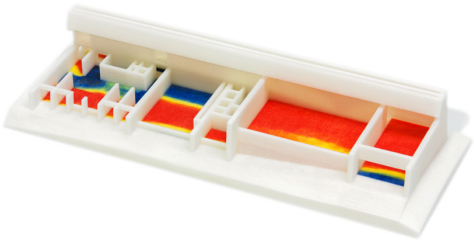
*DAv 300 lux,*
*UDI 100 - 2000 lux*
*Heating, cooling,*
*lighting energy use development*
*(kWh/m²)*
*Primary energy demand*

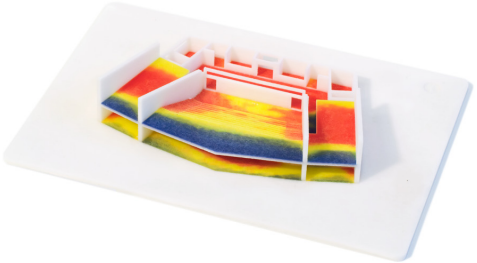
*Florida Office Bldg; Students:*
*R. Canihuante, M. El-Soudany*

*1 Continuous shading balcony*
*2 Horizontal louvers*
*3 Large windows (comfort vent.)*
*4 Shielded interior courtyard*
*5 Short, opaque E/W facades*

*100%* *0% occ. hrs.*

*Below: I.V. de Crego, D. Cepeda + T. Merickova, M. Potrzeba + C. Castillo, R. Georgieva + E. Bahamondes, L. Vasquez*






HYBRID DAYLIGHT MODELS IN ARCH. DESIGN EDUCATION + PARAMETRIC DESIGN

*p. 13 | D. Cepeda, I. Crego presenting, winter 2011/12*

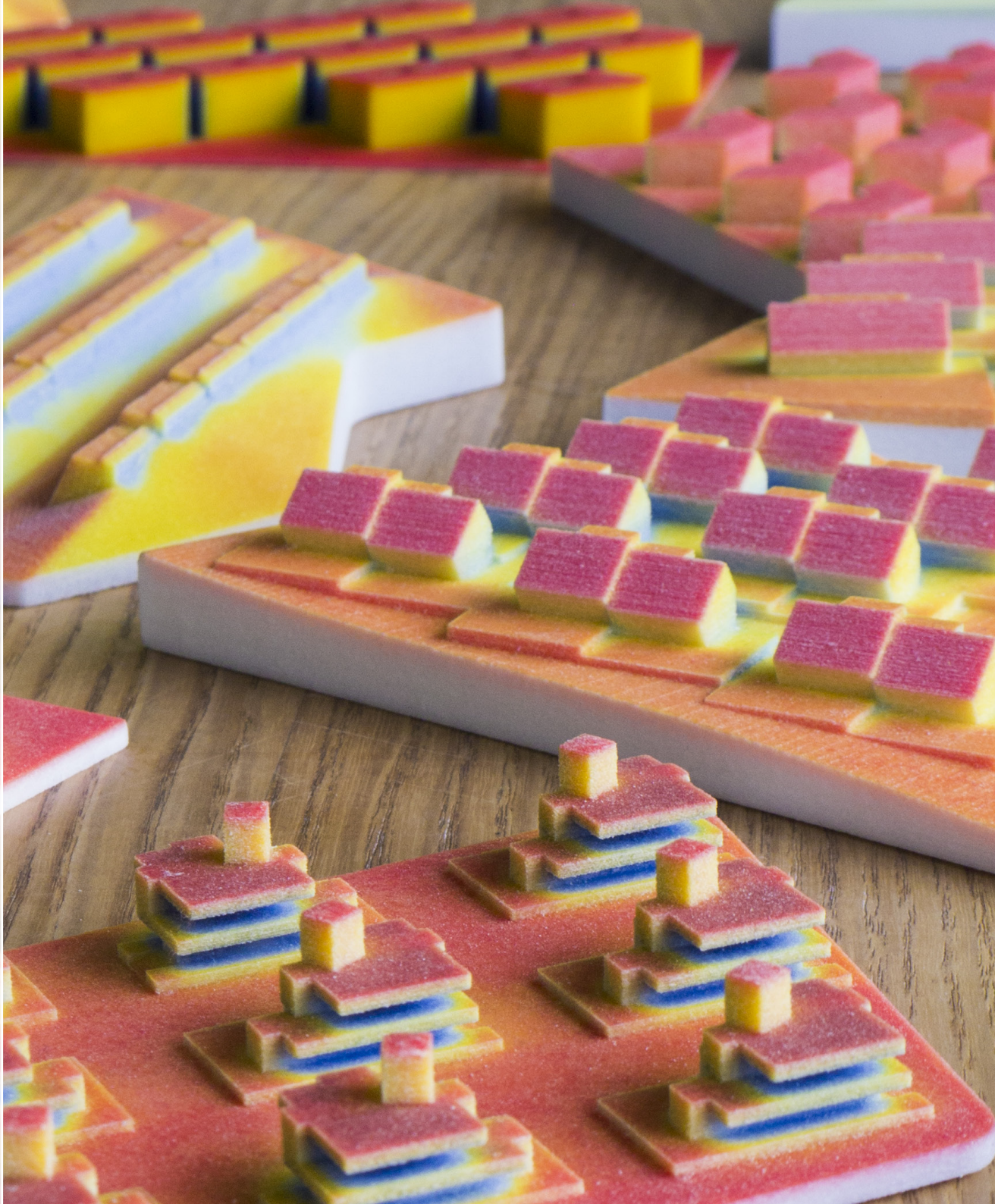
# HYBRID DAYLIGHT MODELS IN ARCH. DESIGN EDUCATION + IRRADIATION PROTOTYPES

*p. 64 | Urban Performance Design Models*

In addition to the daylight models, physical irradiation models played a special part in a retooled urban + housing design studio, as in this instance unit overshadowing, urban layout and individual unit designs closely interlocked. The resultant small-scale models, of which many were produced during a given design process, offer another mode of performance understanding and extend on what was originally written in the paper for CAADRIA 2013 published at the National University Singapore:

"The increasing use of building performance simulation in architectural design enriches digital models and derived prototyping geometries with performance data that makes them analytically powerful artefacts serving sustainable design. [...] Simulation metrics are merged with prototyping geometries to be output on a colour-capable Zprinter; the resultant hybrid artefacts simultaneously allow three-dimensional formal as well as whole-year daylight performance evaluation [and] embody a specific epistemological type that we [...] posit to be an example of multivalent representation, a formal class that aids knowledge accretion in performance-based design workflows."

The following sheets show the performance of two housing class designs compared throughout the ideation process, and use the irradiation models as combined design and performance repositories. Both works were created in Östersund, Sweden's climate; yet as in other classes, multiple climate zones were also used in the urban design seminars.

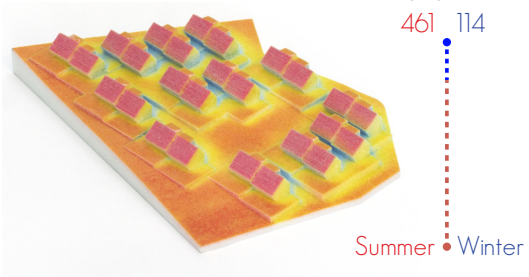


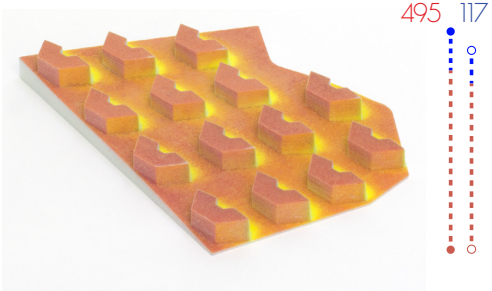
*Background/Opposite:*
*Annual Irradiation, Physically Rapid-Prototyped Urban Design Models. Design: D. Gkougkoudi, O.A. Pearl + T. Merickova, P. Jardzioch + O. Ritter, W. Sutcliffe + C. Kollmeyer, R. Kölmel + N. Vitusevych, W. Fischer Studio, Simulation Prof. + Prototyping: Author*

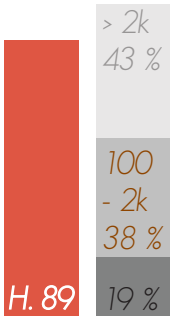
# HYBRID DAYLIGHT MODELS IN ARCH. DESIGN EDUCATION + IRRADIATION PROTOTYPES

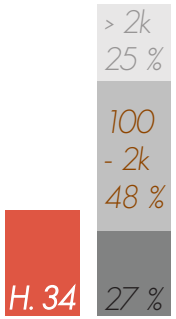
*p. 65 | Sweden (Östersund) Housing Design Performance Comparison*
*Design: O.A. Pearl, D. Gkougkoudi; T. Merickova, P. Jardzioch*
*Studio, Simulation Prof. + Prototyping: Author*

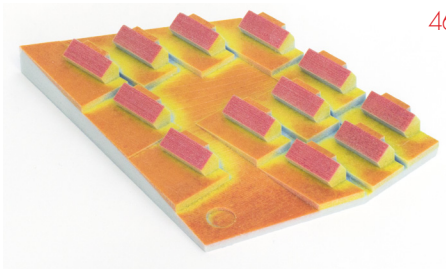
*Students:*
*O. A. Pearl, D. Gkougkoudi*




*Avrg. irradiation (exposed surfaces): kWh/m²*

*Inequal unit performance!*

*Baseline (~A)*

*Final Variant*

*Versioning: compare two site design variants; pick "best" one. Metrics: average irradiance, H/C energy demand (VIPER)*

*"Shaping"*

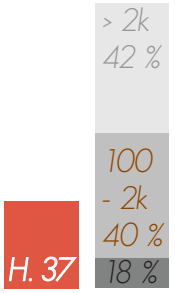
*Test glazing areas, materials, U-values, and unit overshadowing (conditioned & passive)*

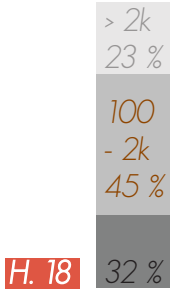
*Daylight UDI 100 - 2000, > 2000 & < 100 lux comparison; Heating energy use development (kWh/m²)*

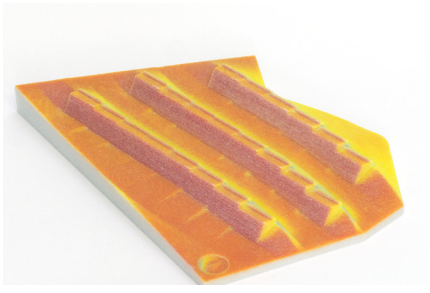
*In parallel to systematic tests, designs continue to develop in a heuristic & design-driven fashion, on multiple levels*

*Students:*
*T. Merickova, P. Jardzioch*





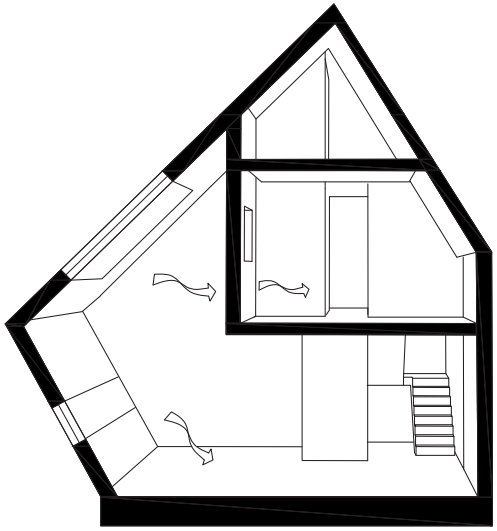




*Baseline (~B)*

*Final Variant*

*p. 66 | Sweden (Östersund) Housing Design Performance Comparison*
*Design: O.A. Pearl, D. Gkougkoudi; T. Merickova, P. Jardzioch*
*Studio + Simulation Prof.: Author*

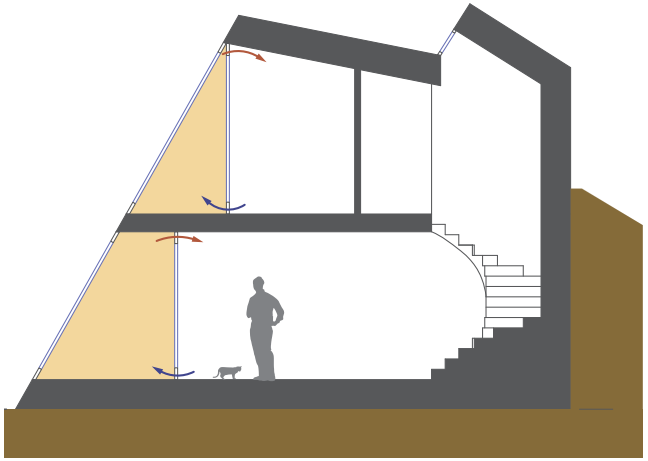
*Students:*
*O. A. Pearl, D. Gkougkoudi*



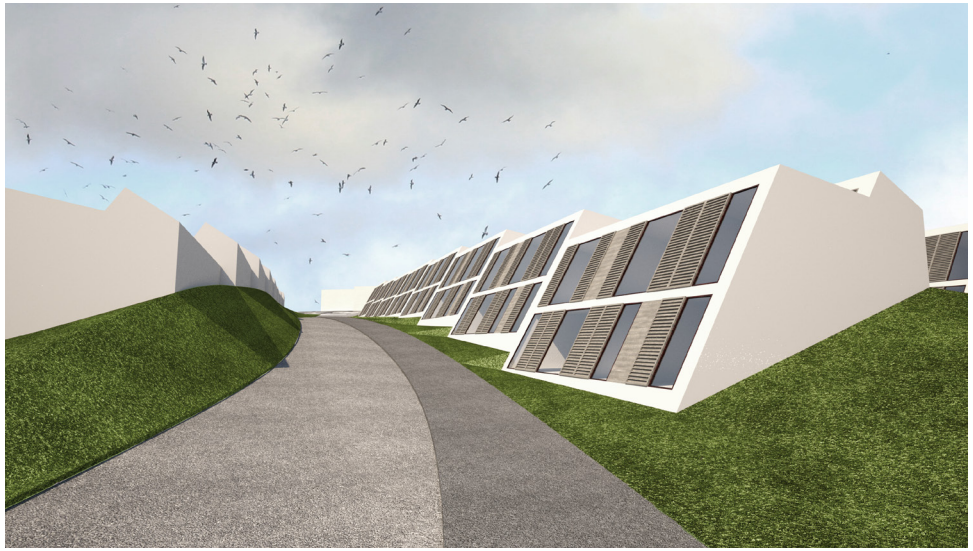
*Unit perspective section*

*Site perspective (looking East)*

*Students:*
*T. Merickova,*
*P. Jardzioch*



*Unit section*



*Site perspective (looking West)*