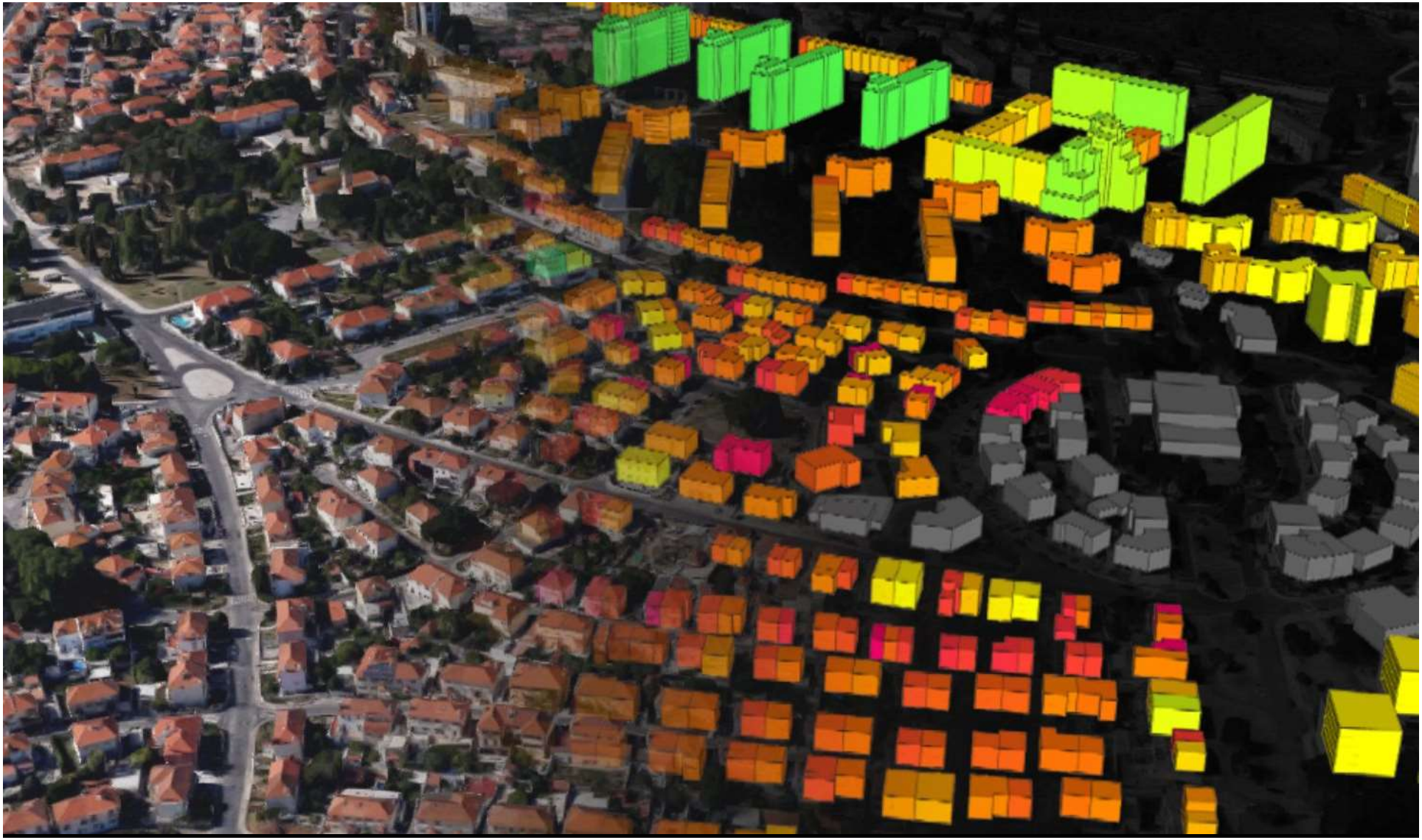

A new Look At Old Buildings

Christoph Reinhart*, Claudia Sousa Monteiro*, Carlos Cerezo Davila, Alpha Arsano, Irmak Turan, Khadija Benis*

*) Will be presenting today.

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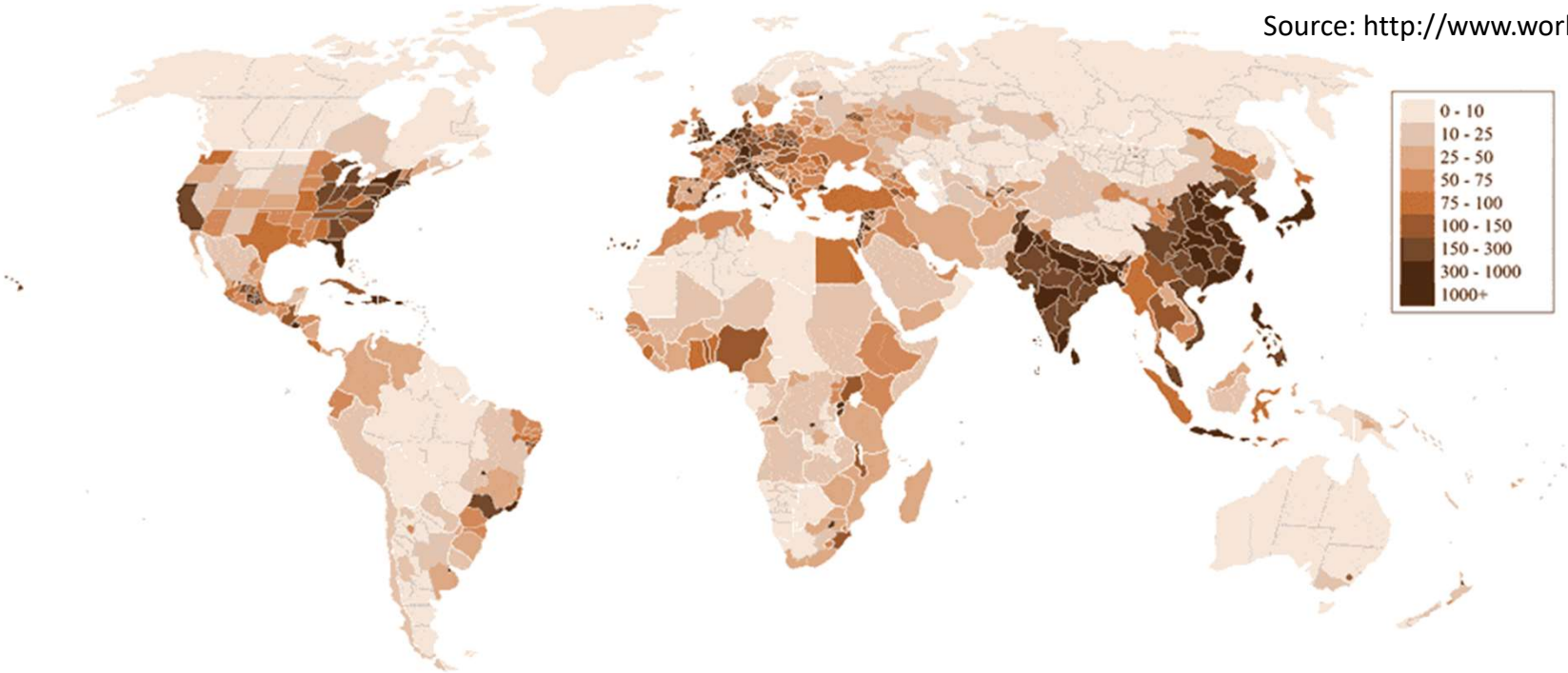
The World is goes to Town

Source: http://www.worldometers.info



Cities worldwide will have to house up to 1.5 billion new city dwellers in 15 years which corresponds to a net growth of two million per week.

Many cities have set carbon emission reduction targets between 20% and 60% by 2030.

We need decision support tools to help cities to meet these goals while staying livable and financially competitive.

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Our Approach

Develop and validate an environmental urban data model of parts of Lisbon to help Lisbon municipality to address their challenges regarding:

- ❑ Building energy use
- ❑ Resident comfort in a warming climate
- ❑ Access the daylight
- ❑ Local food production

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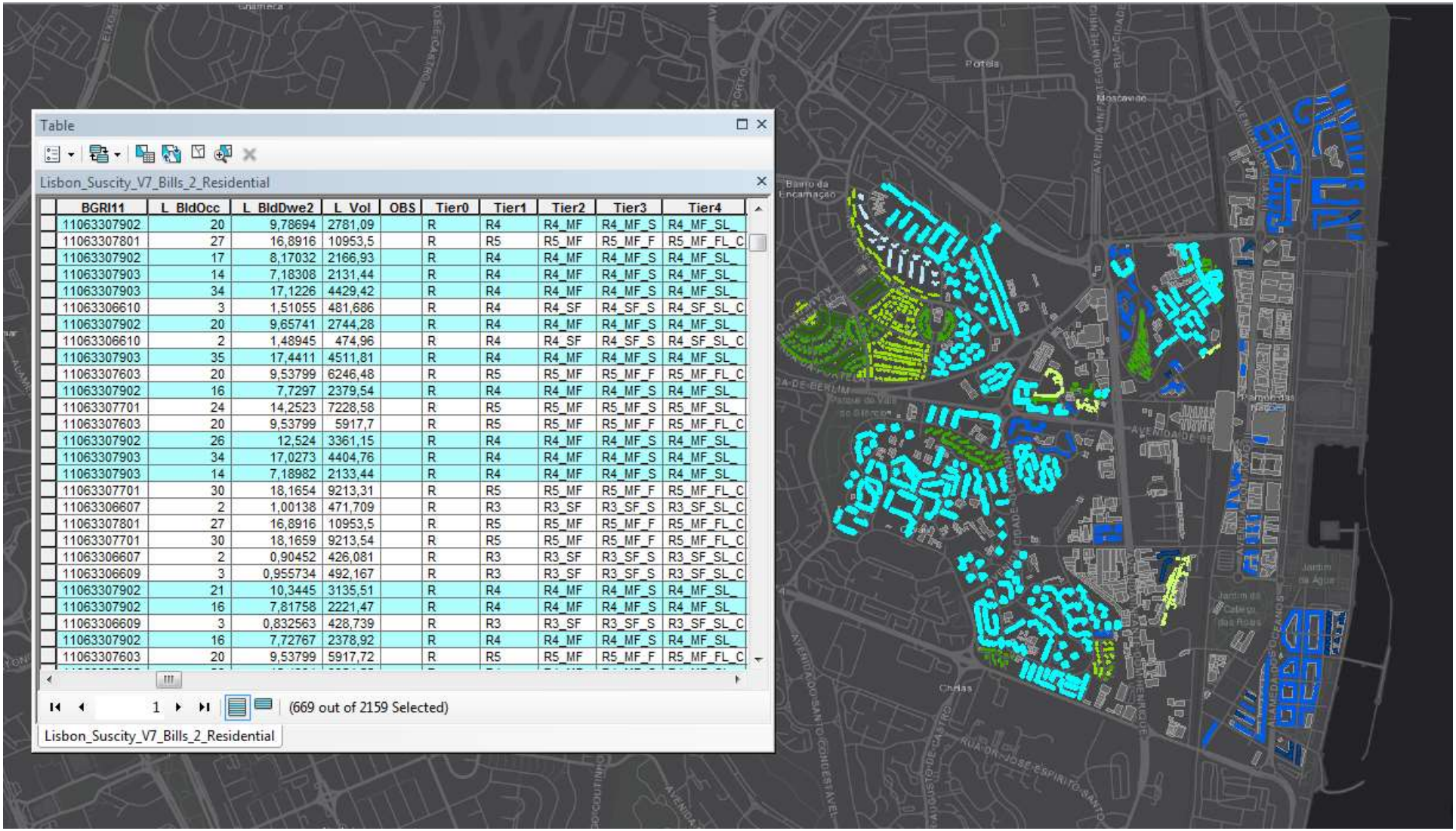
MIT SUSTAINABLE DESIGN LAB

Home | Projects | Publications | Teaching | Software | News | **People**

Lab Hike 2016 | Alpha, Irmak, Jiamin, Cody, Carlos, Shreshth, Nathaniel, Jay, Jamie, Christoph

web.mit.edu/SustainableDesignLab



Building and energy data accessibility in Lisbon

Claudia Sousa Monteiro/ IST

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Motivation

THE STRATEGIC CHARTER OF LISBOA 2010-2024 - A COMMITMENT FOR THE FUTURE OF THE CITY

Strategic questions:

…

How to turn Lisboa into an environmentally sustainable and energetically efficient city?

…

Carta Estratégica Lisboa 2010/24

Measures to be adopted

- Building's energy certification
- Enhance renewable energy
- Building's retrofit
- Construction residuals
- Improve public building's energy efficiency
- Increase green areas and reduce heat island effect
- Encourage town center settlement – tax incentives
- Solar orientation and geometry in buildings and public spaces
- Reduce, re-use and recycle of resources

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Challenge

Scientific models → Quantify the improvements

Urban modeling interface – UMI
https://architecture.mit.edu/building-technology/project/urban-modeling-interface

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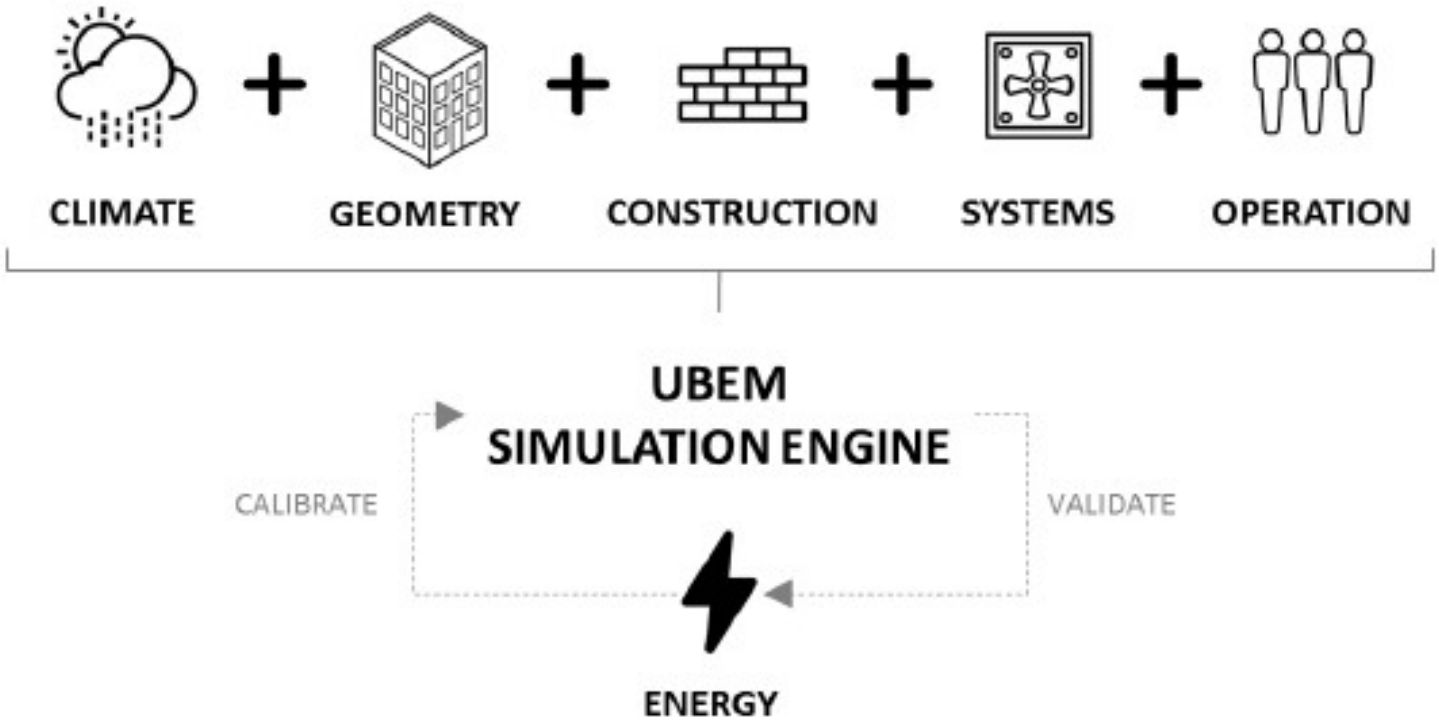
Necessary input data for UBEMs

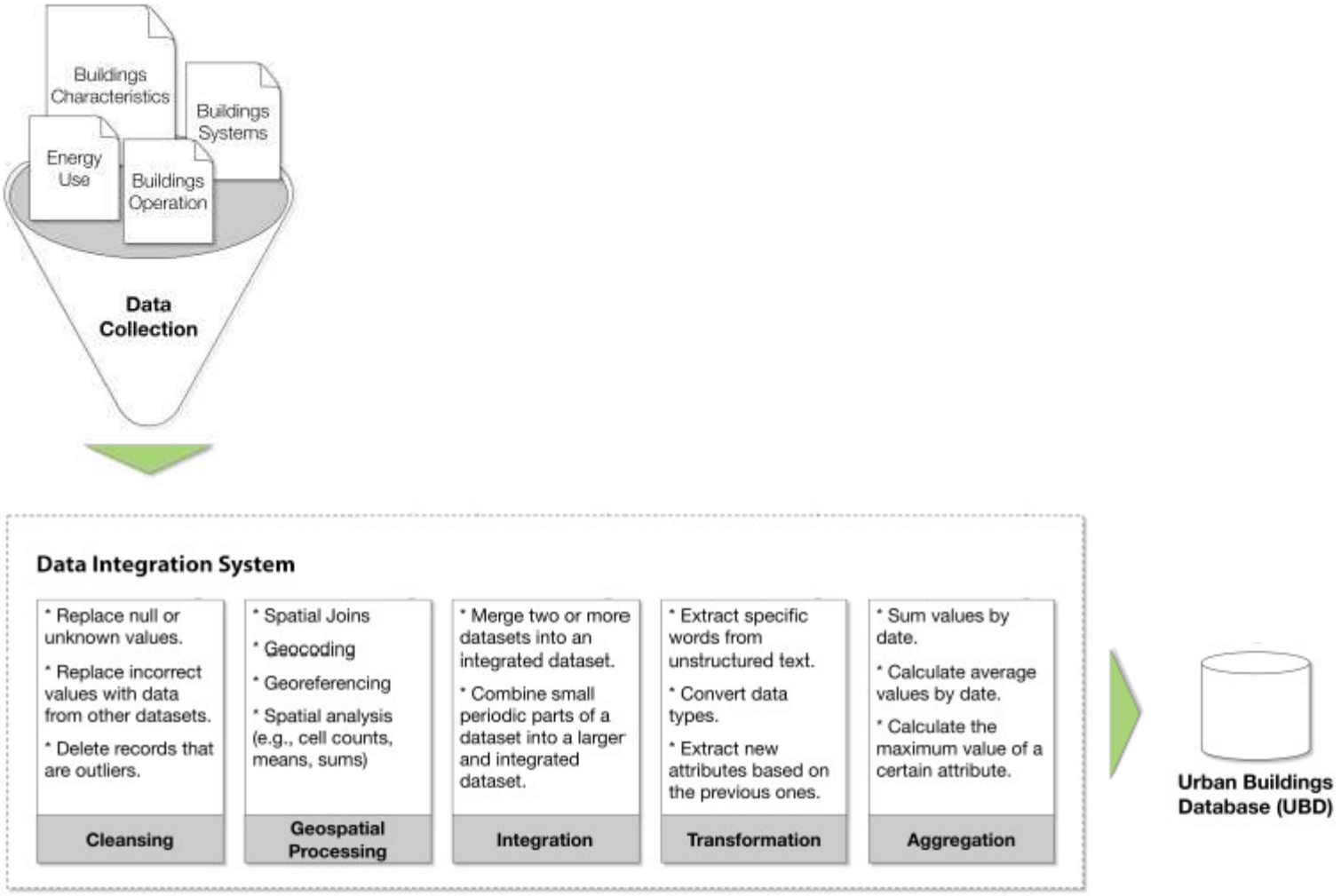


Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

Where to find these data?

Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

How to make this data ‘useful’?



Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) ‘An urban building database (UBD) supporting a smart city information system’, Energy and Buildings, 158, pp 244-260

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Limitations found

Data integration
Datasets do not share a common identification or a common geographic feature

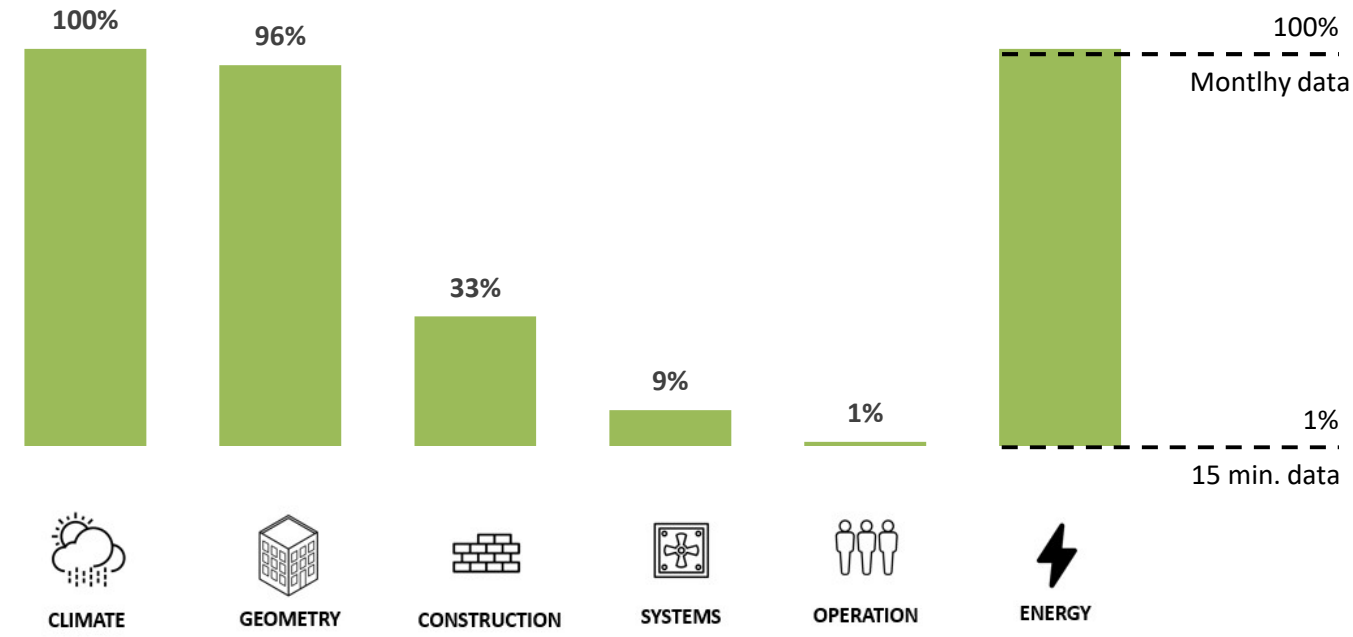
Data accuracy
Outdated, default and incomplete data

Data privacy
Limited data access, coverage and resolution

Data coverage
Inconsistent dataset due to data asymmetry (missing data)

Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

Limitations found



Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

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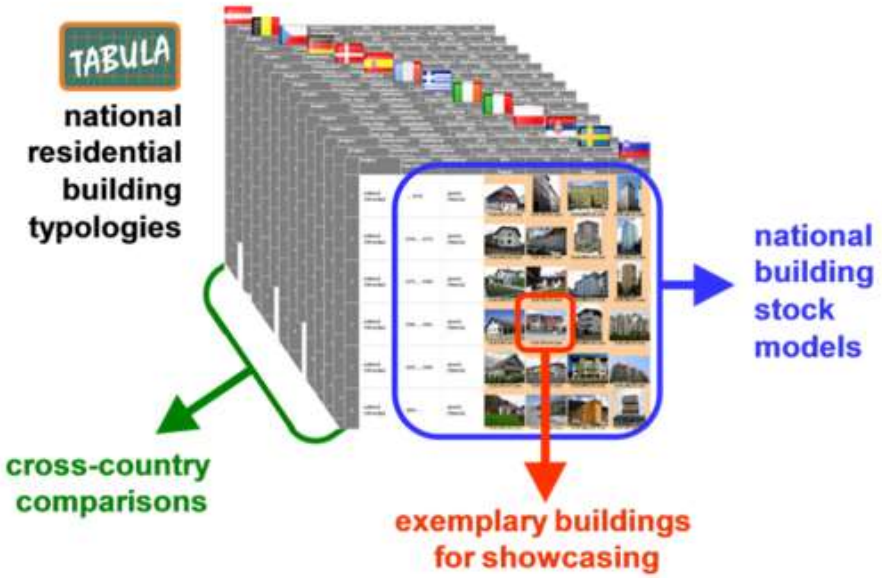
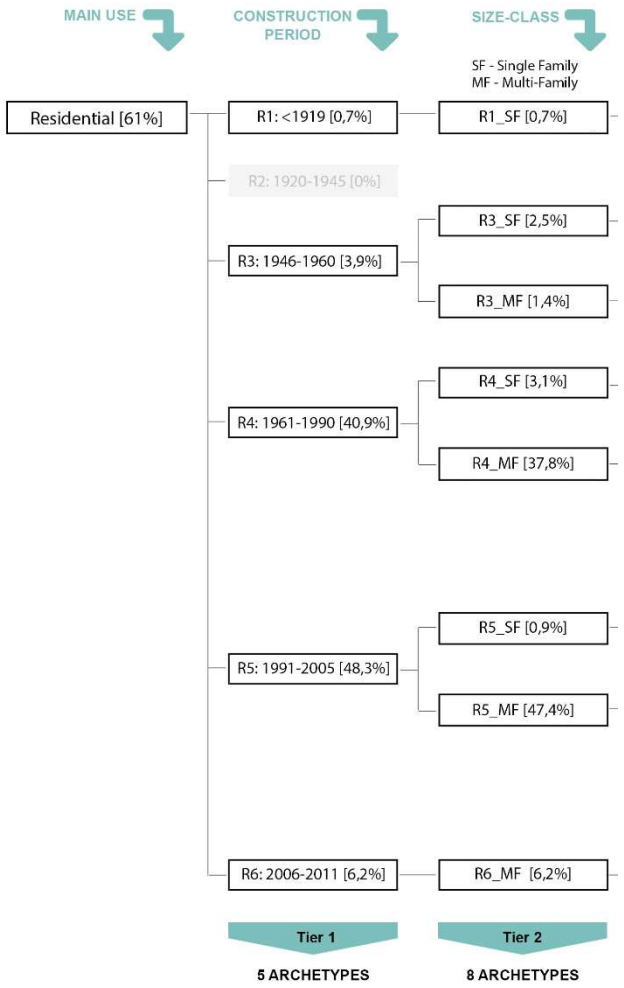
Building archetypes

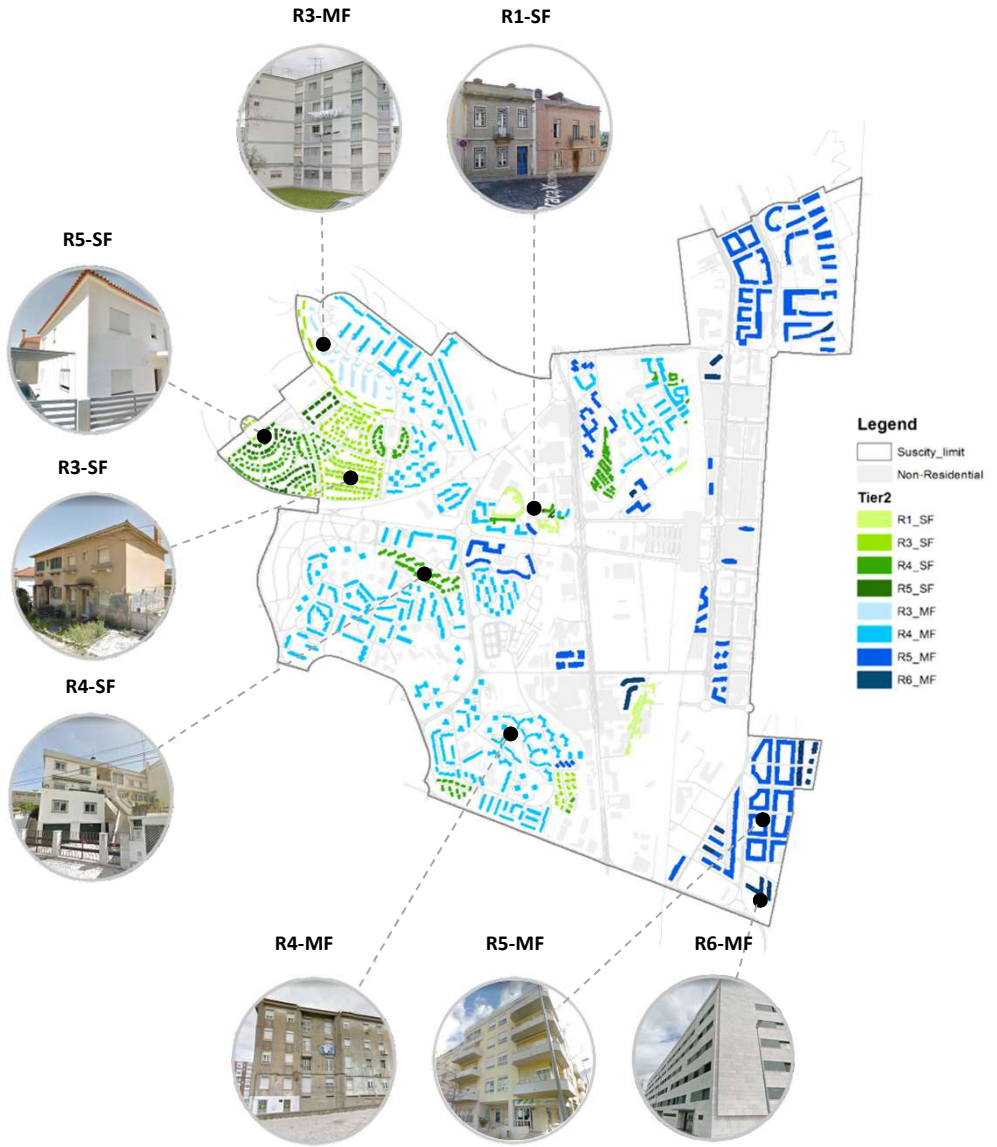
Typology Approach for Building Stock Energy Assessment (TABULA)
Covered Countries and Involved Organizations



http://episcope.eu/welcome/

Building archetypes





Sousa Monteiro, Panão, Pina, Ferrão (2018) 'The Use of Multi-detail Building Archetypes in Urban Energy Modelling', submitted

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How to improve UBDs?

Let's work together
Share common ID or geographical database
Share information across different datasets

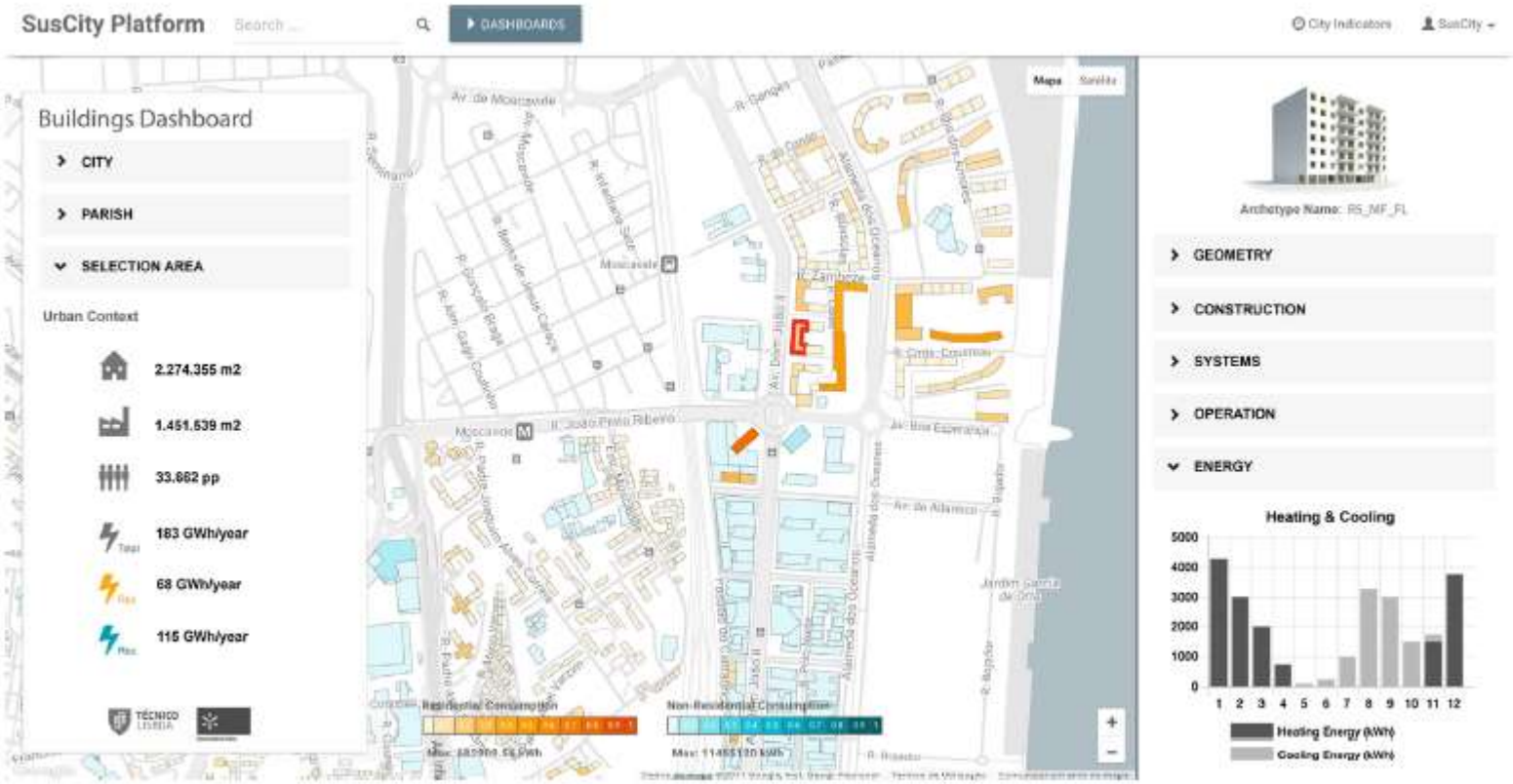
Take good care of your data
Inspection on data accuracy
Scheduled updates of raw data
Establish data sharing protocols

Boost people engagement
Geo-visualization to empower confidence in data sharing
User-friendly interface allowing citizen collaboration and feedback
Periodical surveys on the use of time and energy consumption

Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

How to improve UBDs?

SusCity Platform – Buildings Dashboard



Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

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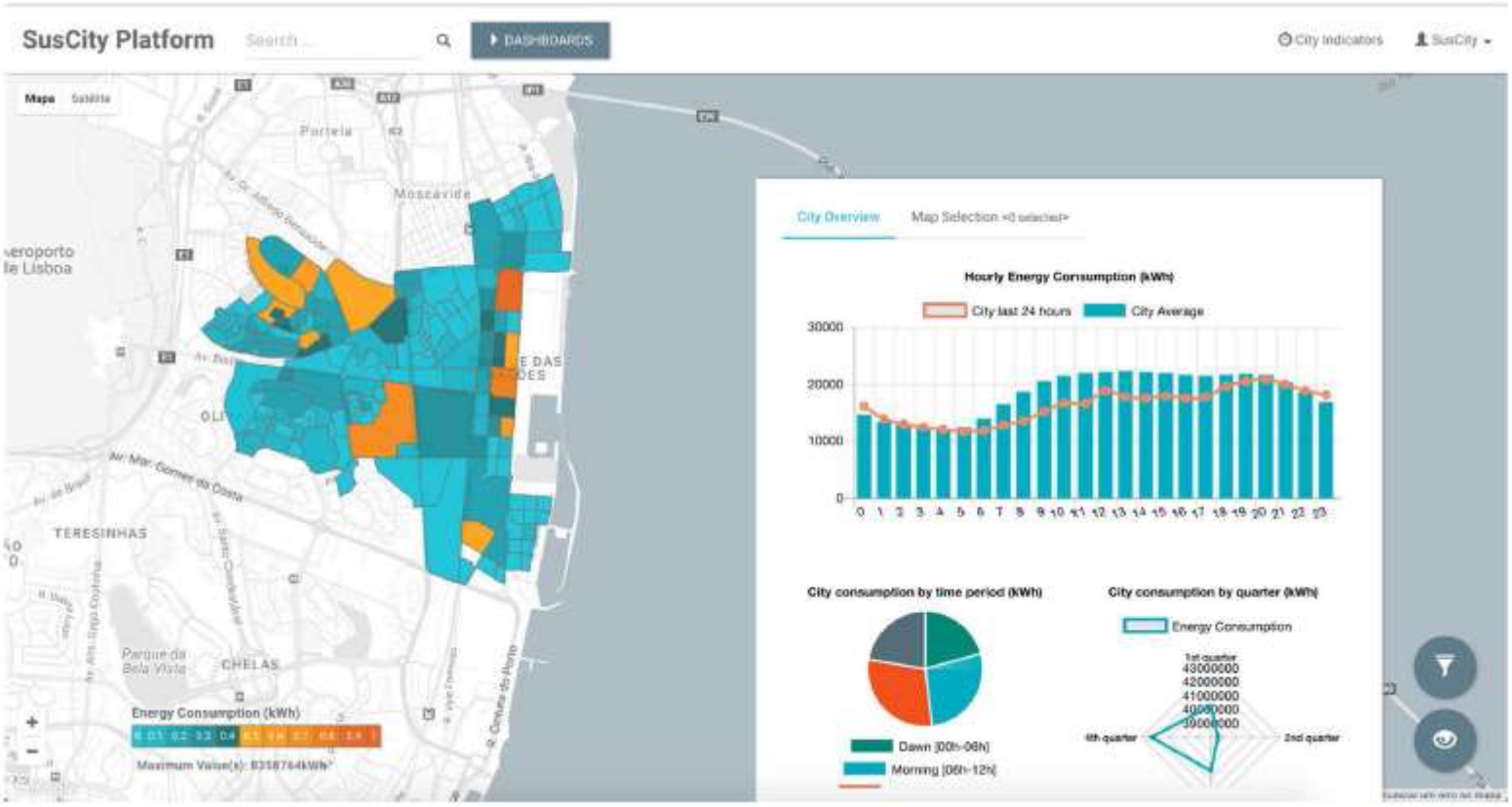
How to improve UBDs?

SusCity Platform – Buildings Dashboard



Sousa Monteiro, Costa, Pina, Santos, Ferrão (2018) 'An urban building database (UBD) supporting a smart city information system', Energy and Buildings, 158, pp 244-260

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Summary of key ideas

Framework on how to create an UBD
Necessary data
Sources and datasets available
Data integration system

Building archetypes dataset for Lisbon

Guidelines on how to improve data gathering and integration
Let’s work together
Take care of your data
Boost people engagement

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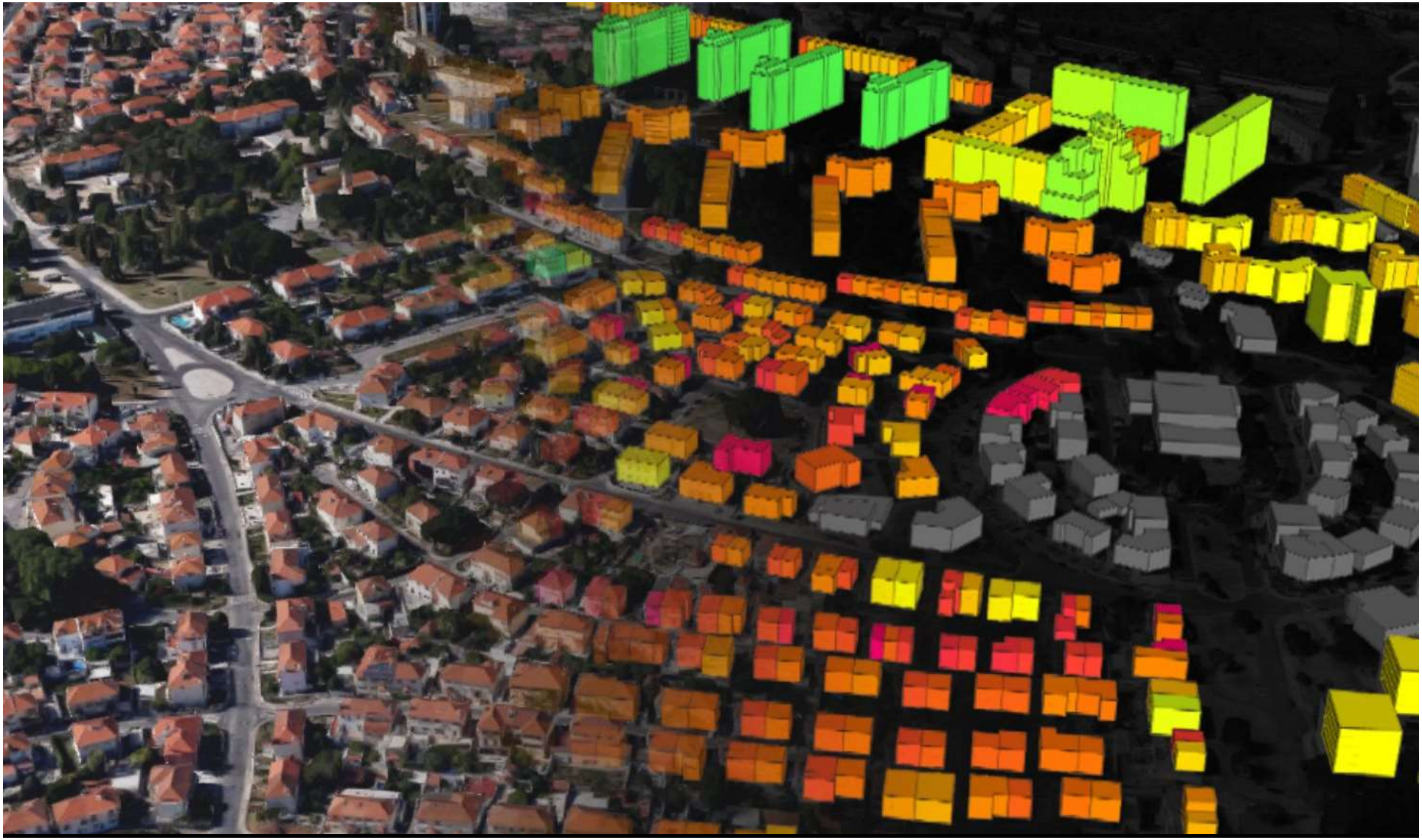

Modeling urban energy demands in Lisbon

Carlos Cerezo Davila / MIT

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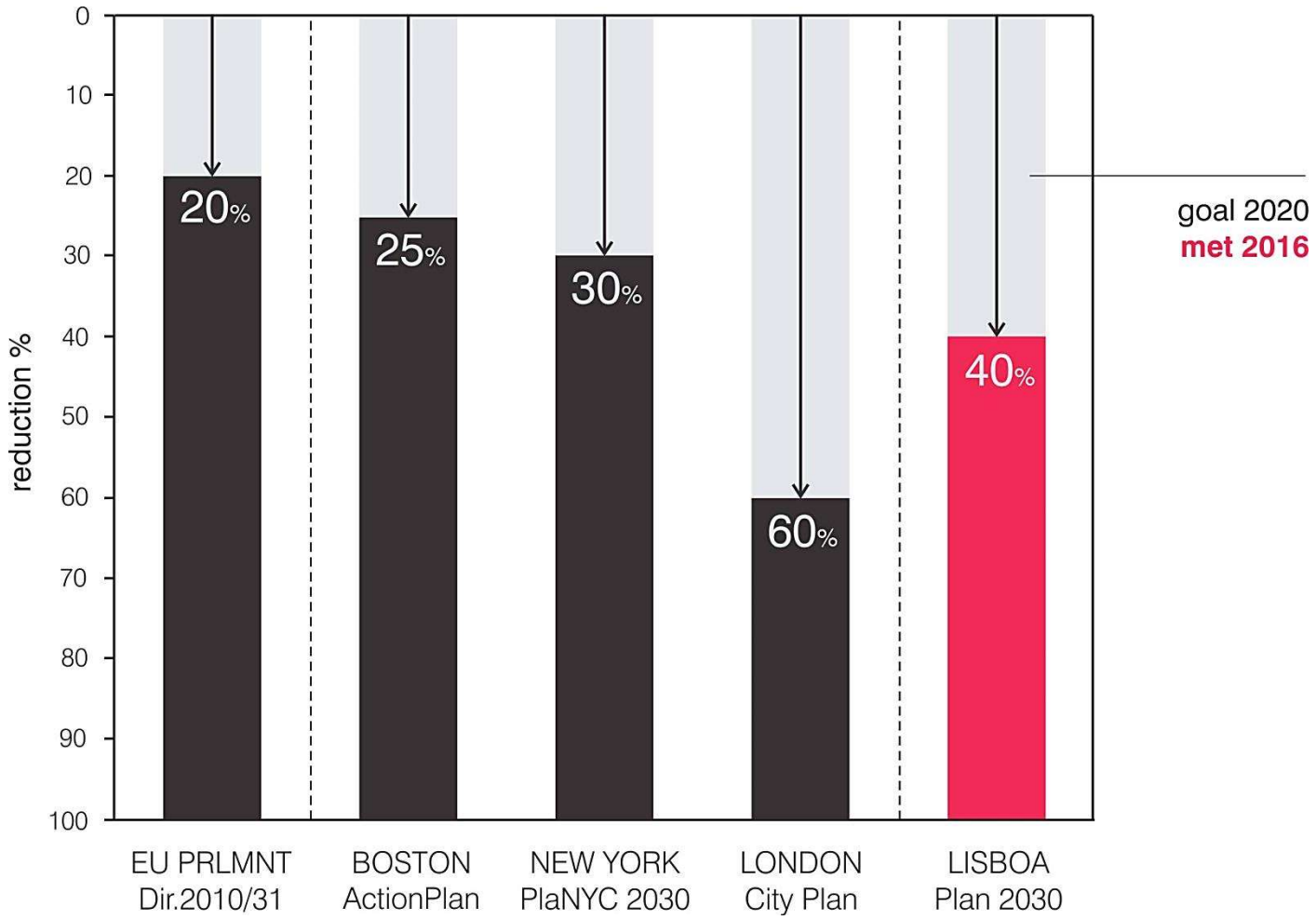
Urban emission reduction goals



Planned emission reduction for 2030 by city

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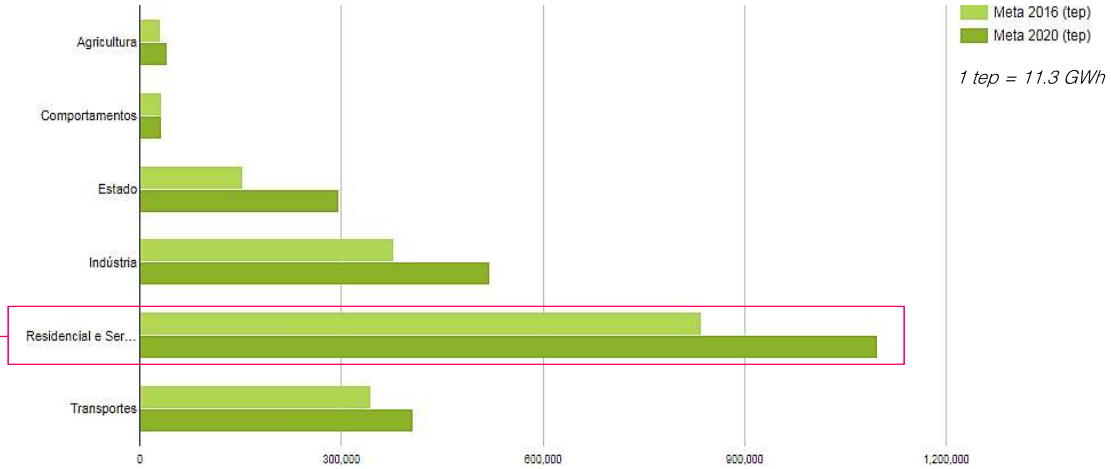
Portugal national energy strategy

PORTUGAL RECUCTION GOALS



LISBOA REDUCTION GOALS

Sector Residencial	*Primary Energy Reduction 2020* **GWh**	*Carbon Reduction 2020* **ktCO2**
Renovação de electrodomésticos por equipamentos mais eficientes	407	104
Substituição de lâmpadas incandescentes por lâmpadas mais eficientes	459	118
Aumento do desempenho energético em remodelações e novos edifícios residenciais	428	104
Aumento da implementação de sistemas de tecnologia solar fotovoltaica	5	2
Aumento da implementação de sistemas de utilização de energia solar térmica	66	15

Governo de Portugal (2013/2016) “Plano Nacional de Acção para la Eficiência Energética (PNAEE)”
Lisboa ENOVA (2008) ‘Plano de Acção para a Sustentabilidade Energética de Lisboa’

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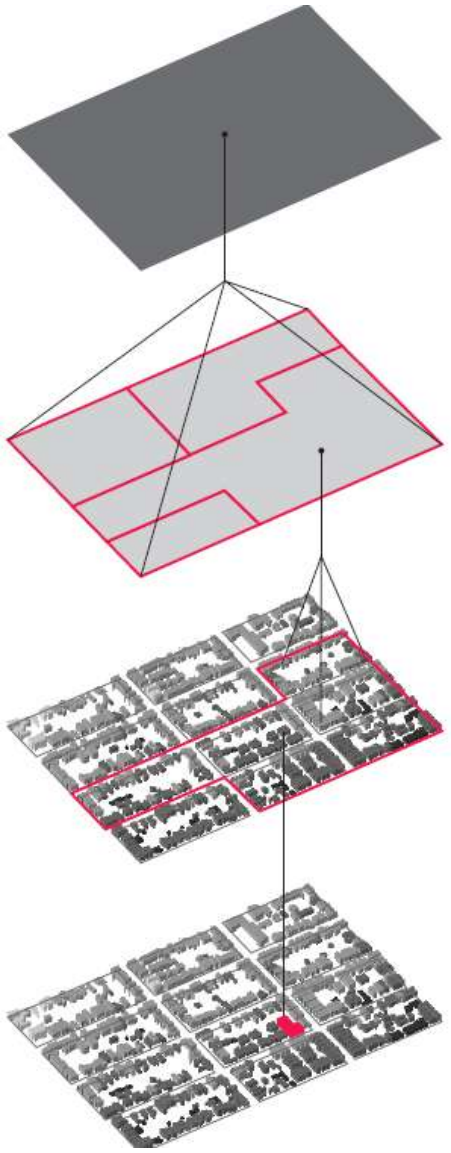
The energy data gap

POLICY TARGETS

?

SPECIFIC STRATEGIES



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The energy data gap

POLICY TARGETS

Urban Planning

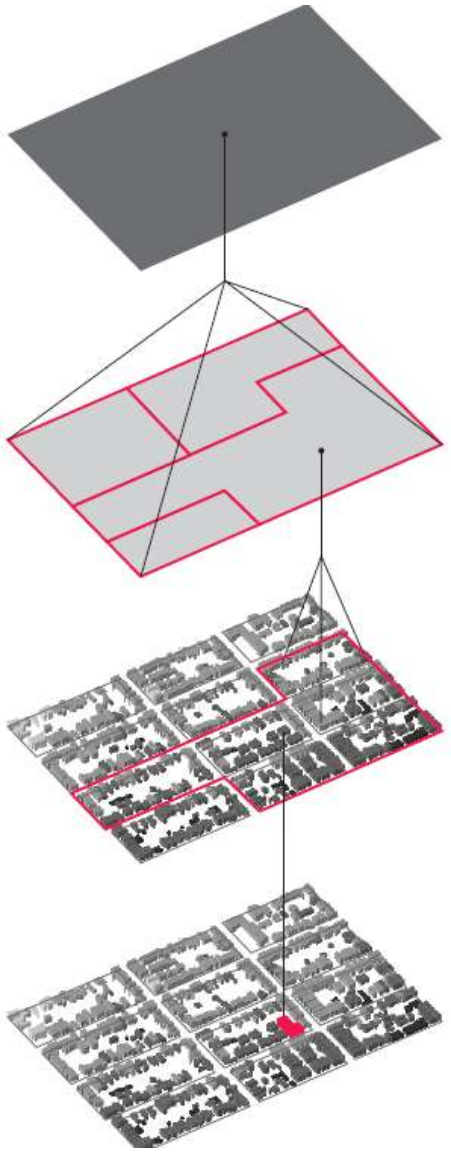
Zoning rules
Building regulations

Urban Design

Solar generation
Micro grids
Shading context

Architecture

Envelope design
Daylight and ventilation
Building systems



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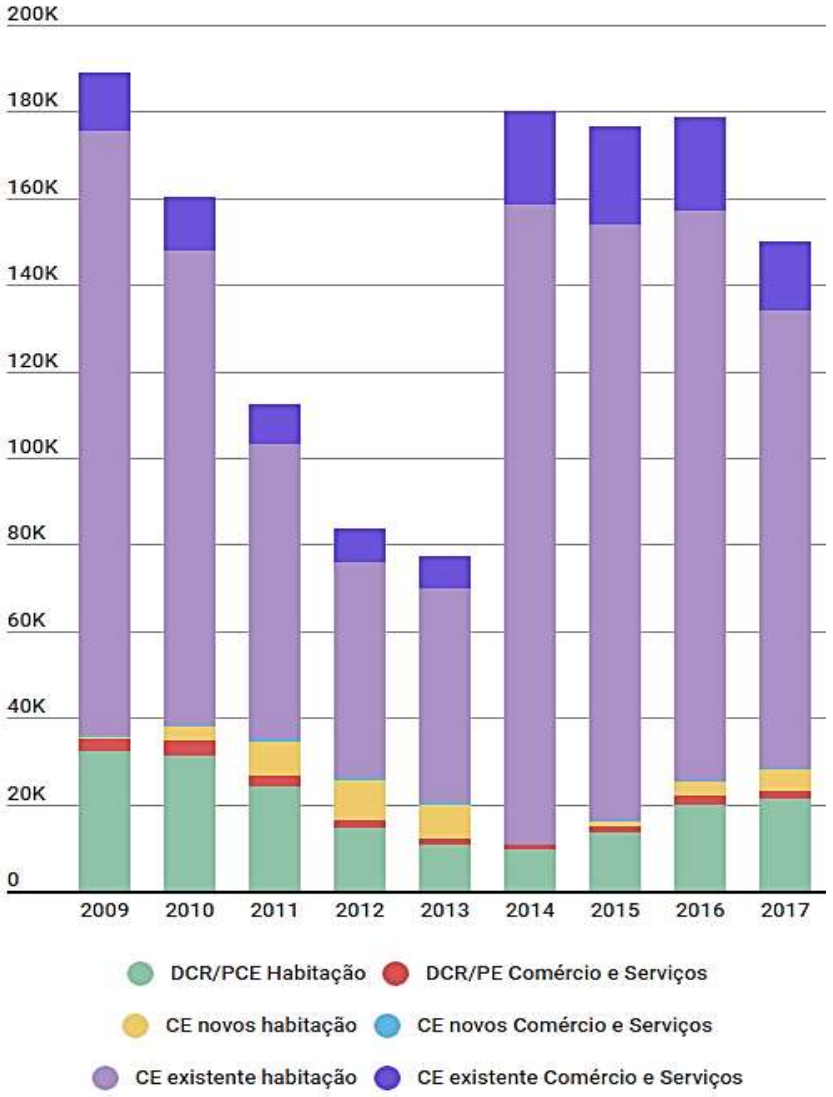
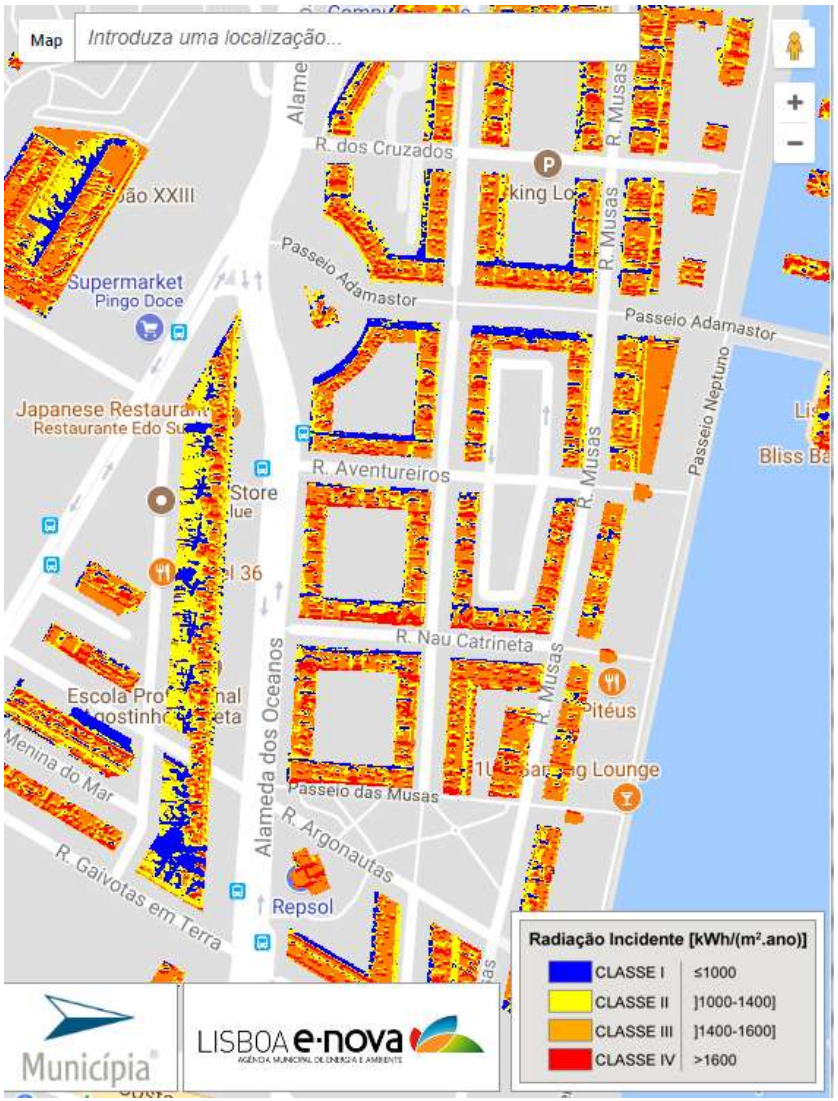
Ongoing efforts in Portugal and Lisbon





ADENE (2017) 'Certificação Energética dos Edifícios: Estatísticas", URL: www.sce.pt
Lisboa Enova (2012) 'Solar potential map', URL: http://lisboaenova.org/en/cartasolarlisboa

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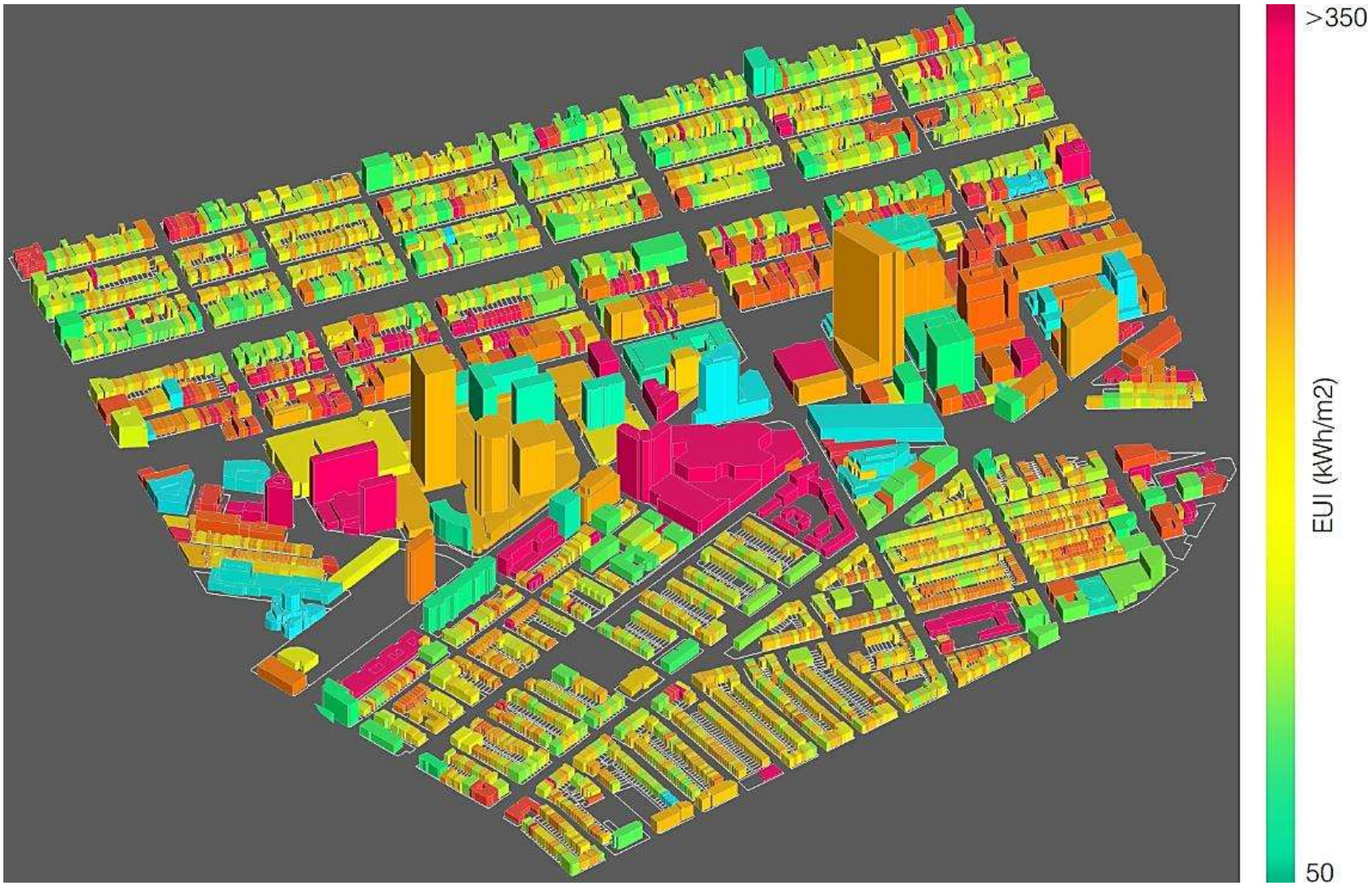
Urban building energy models (UBEMs)



Simulated EUI by building in Boston

Cerezo, Bemis, Reinhart (2016) 'Modeling Boston: A workflow for the generation of complete urban building energy demand models from existing GIS' Energy 117, 237 – 250

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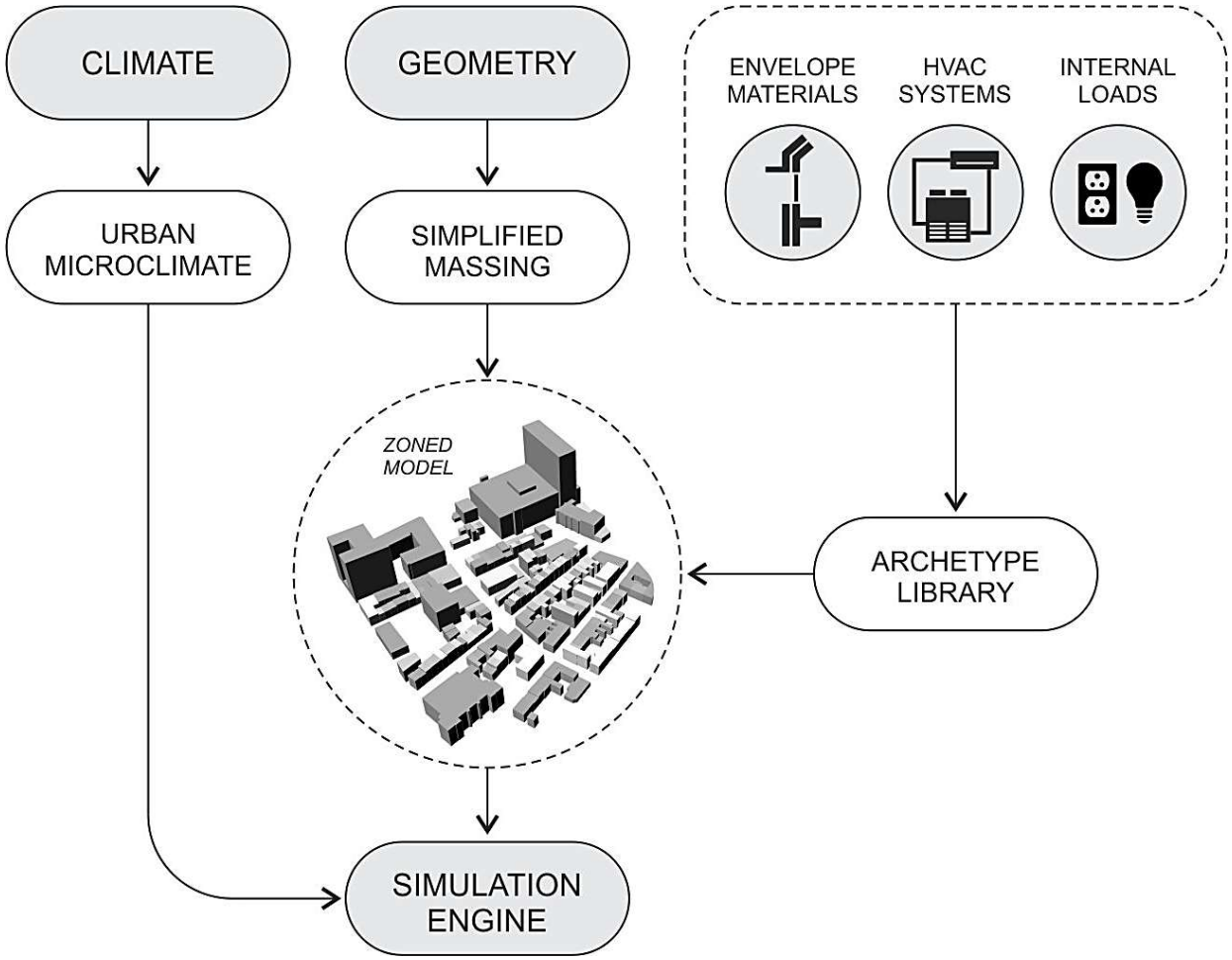
What do we need to build and UBEM?



Reinhart, Cerezo (2015) 'Urban Building Energy Modeling - A Review of a Nascent Field', Buildings and Environment 2016, 97: 196–202

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Urban modeling workflow

Automated model generation in Rhino3d
(www.youtube.com/watch?v=O46GkHSYvYE)

Cerezo, Bemis, Reinhart (2016) 'Modeling Boston: A workflow for the generation of complete urban building energy demand models from existing GIS' Energy 117, 237 – 250

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Case study residential districts

Olivais N / Encarnacao

867 buildings
50% Period 3
35% Period 4
15% Period 5

Cabo Ruivo

139 buildings
92% Period 5
8% Period 6

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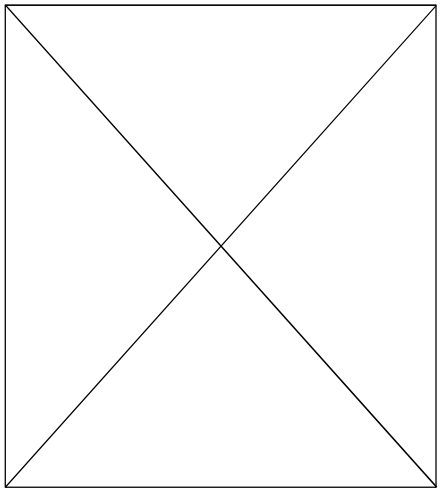
Archetype database for residential buildings

Single Family (1946-1960)

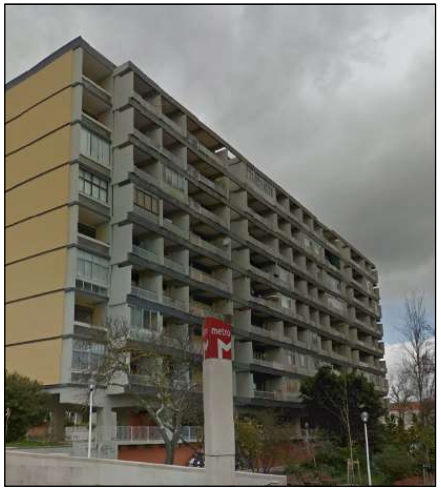
Single Family (1961-1990)

Single Family (1991-2005)



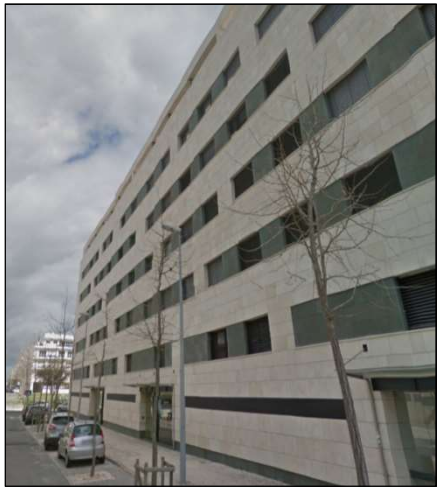
Single Family (2006-Now)

Multi Family (1946-1960)



Multi Family (1961-1990)

Multi Family (1991-2005)



Multi Family (2006-Now)

Montero, Pina, Cerezo, Reinhart, Ferrao (2017) 'The Use of Multi-detail Building Archetypes in Urban Energy Modelling', Energy Procedia 111, 817-825

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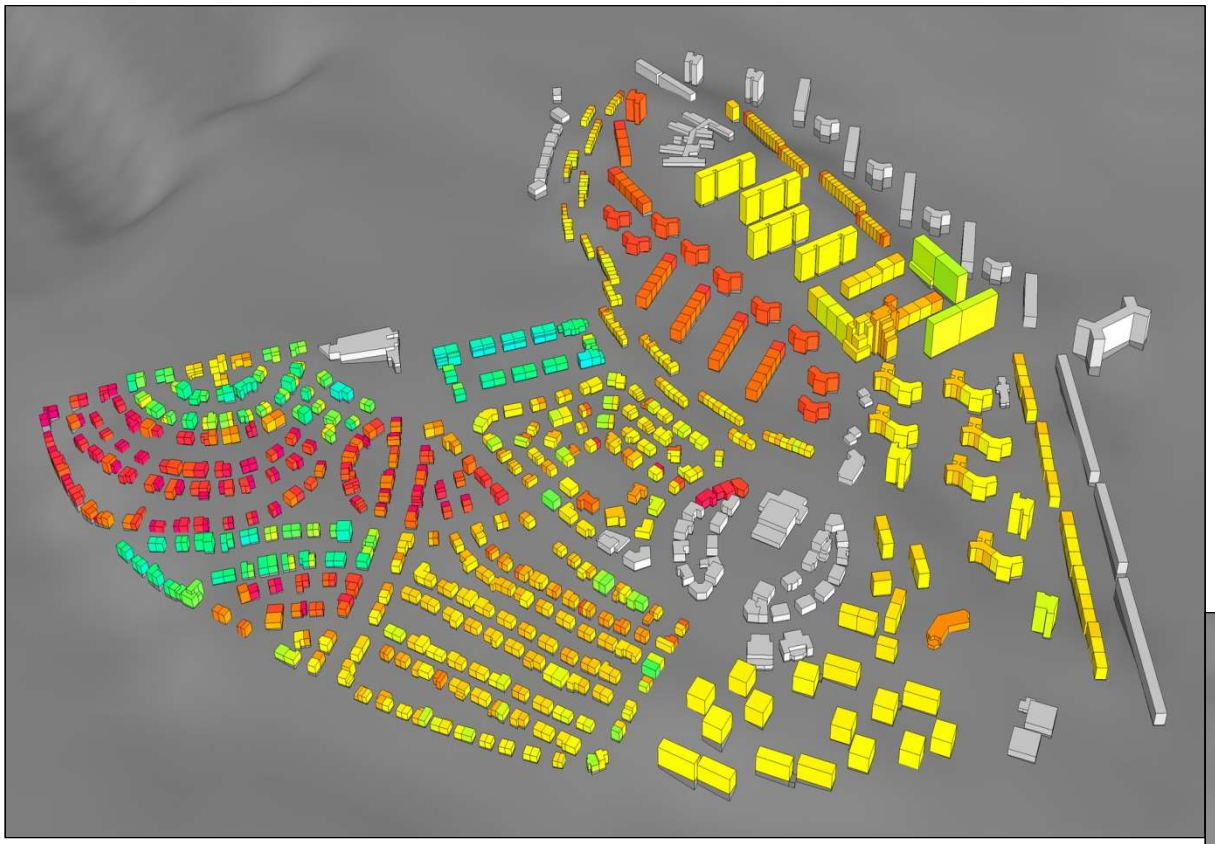
Mapping building energy demands



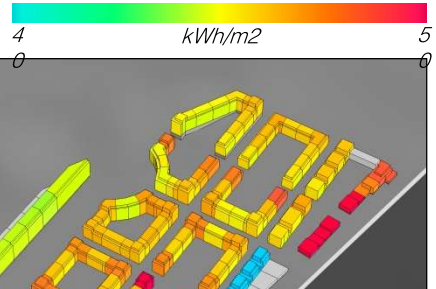
4 0 kWh/m2 6 0

Olivais / Encarnacao

Average EUI = 52 kWh/m2

Cabo Ruivo

Average EUI = 45 kWh/m2



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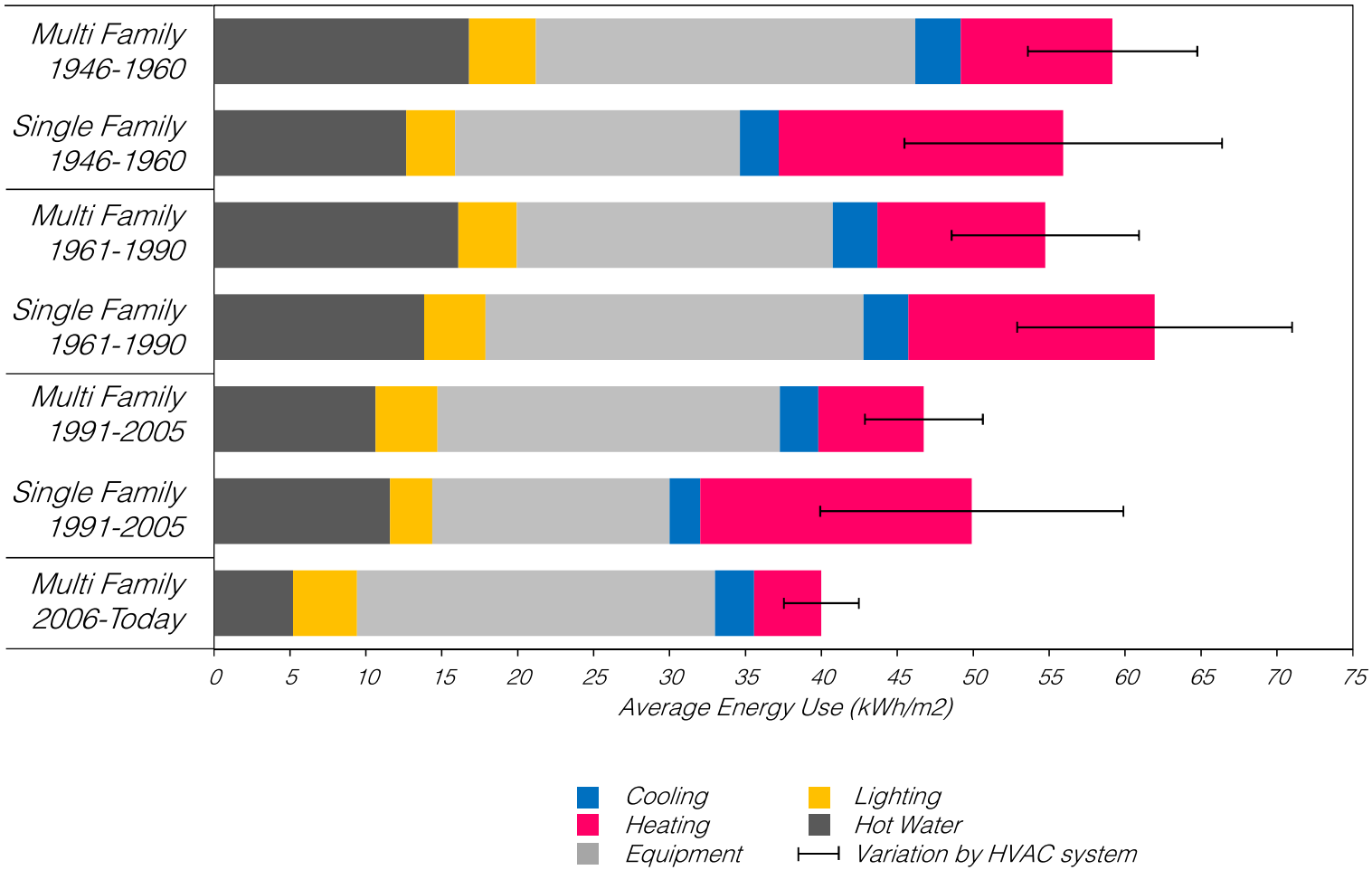
Energy demands by archetype



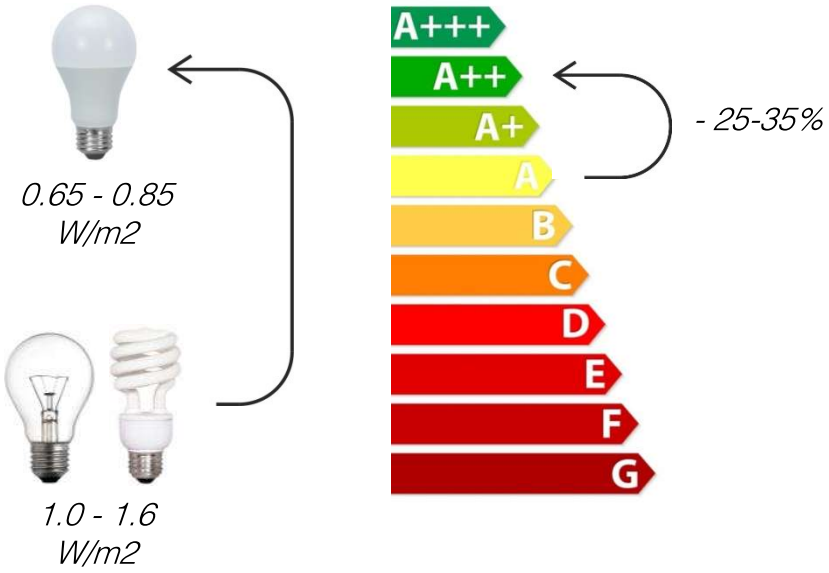
Average energy use by building type and age

Mapping energy efficiency policy

SCENARIO 1

Envelope and glazing upgrade

- *The insulation in all facades and roofs is increased to match Portugal's energy code U value requirements.*
- *All windows are assumed to be replaced as well, to match code requirements for U value and SHGC.*



SCENARIO 2

Lighting and appliances upgrade

- *The current mixture of fluorescent, compact and halogen lights is replaced by a majority of LED lightbulbs (42% reduction in peak lighting power density).*
- *Main home appliances such as refrigerator, oven, and washing machine, are replaced by high efficiency ones (from A to A++).*

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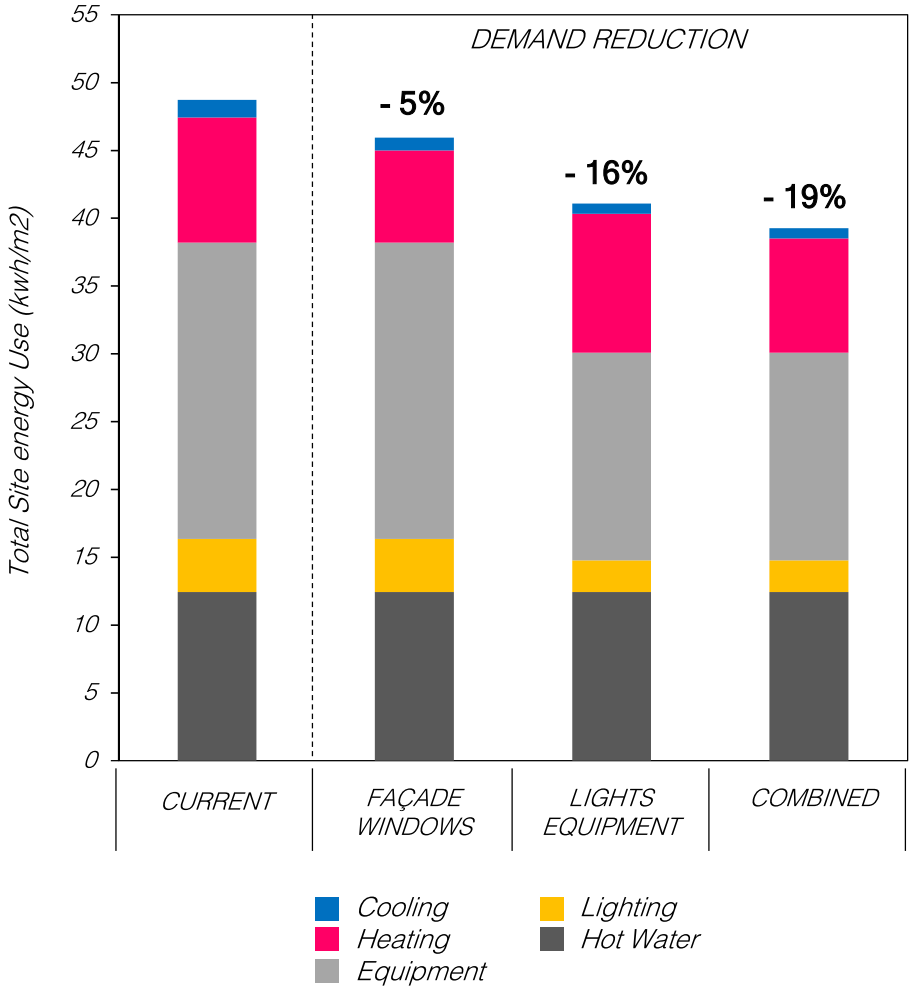
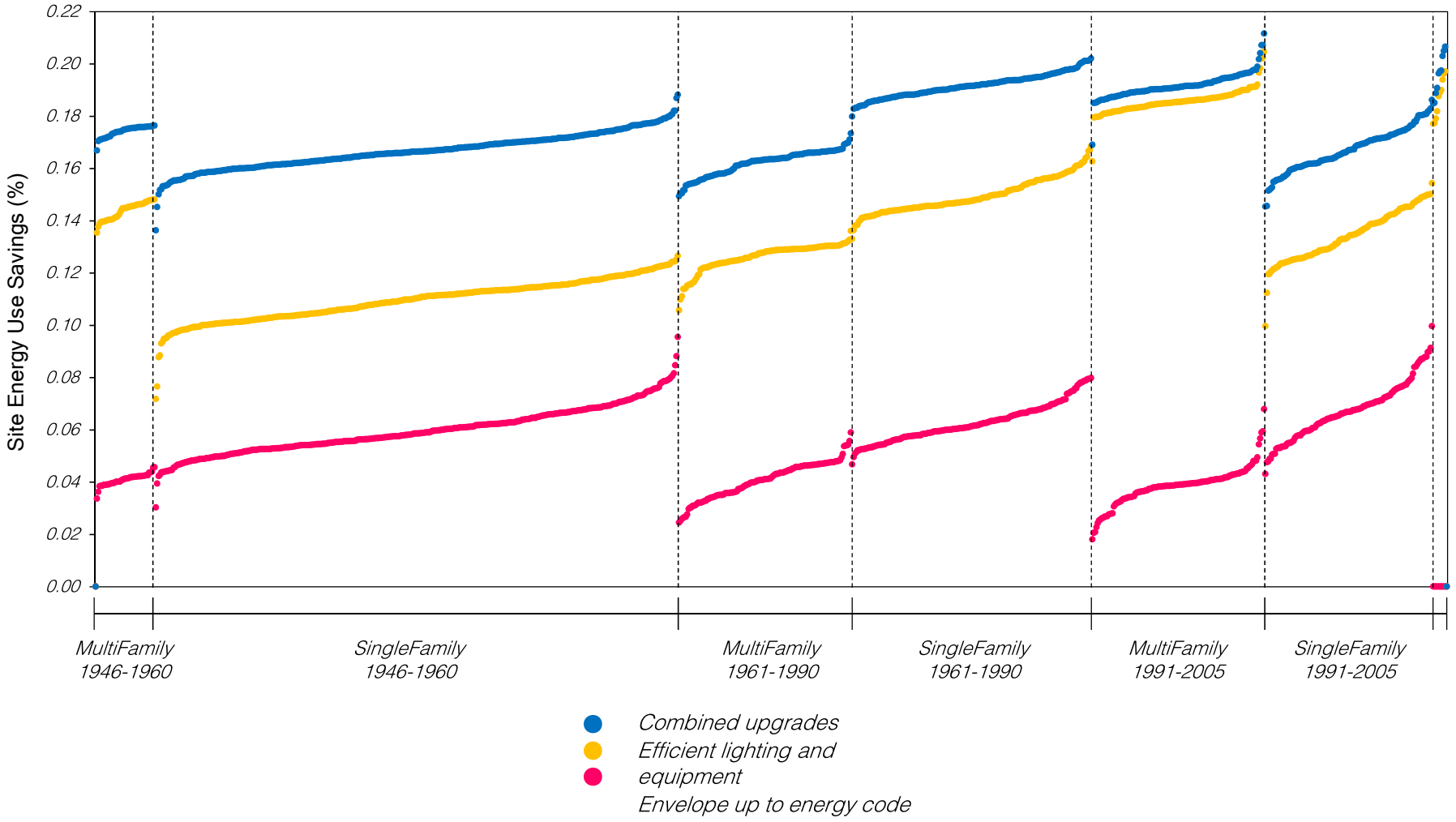
Aggregate potential savings



Average energy use by efficiency scenario

How does it apply by archetype?



Energy savings by building and upgrade scenario in Olivais/Encarnacao/CaboRuivo

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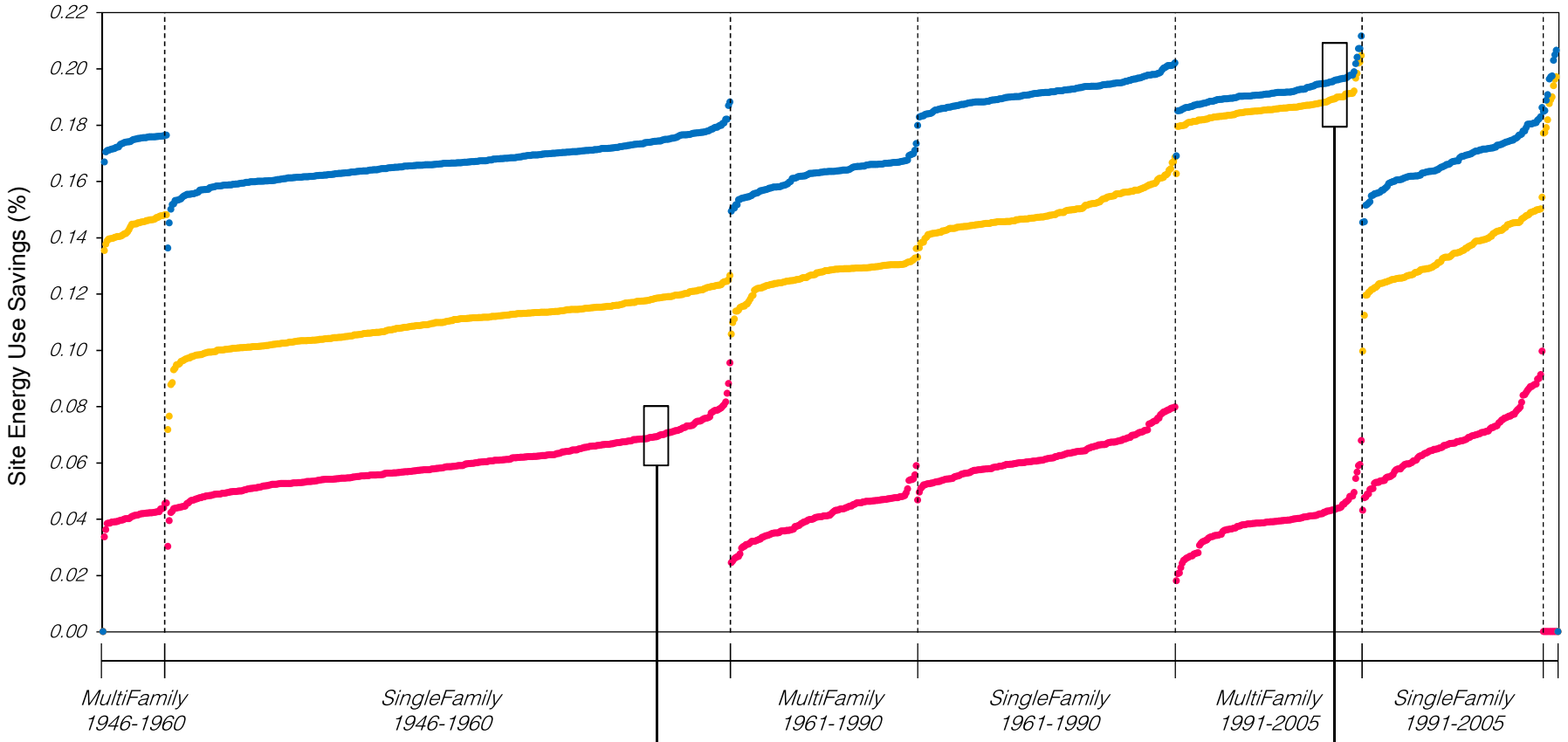
How does it apply by archetype?



Single Family home (Olivais)
12% lgt/eqp
7% fac/win

Apartment building (Cabo Ruivo)
19% lgt/eqp
4% fac/win

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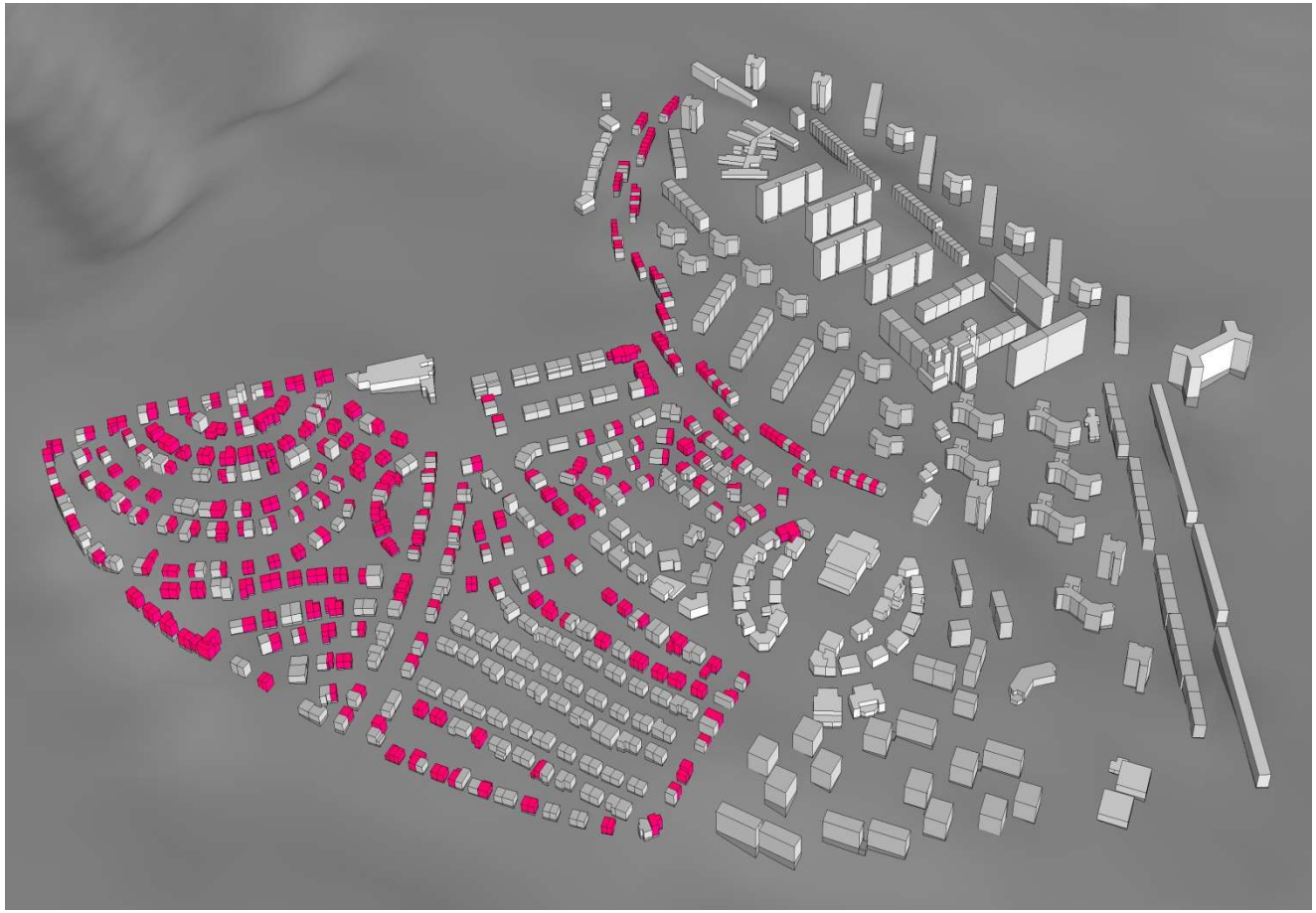
Targeted energy efficiency strategies



Savings > 5% when improving envelope
642 buildings in Olivais / Encarnacao

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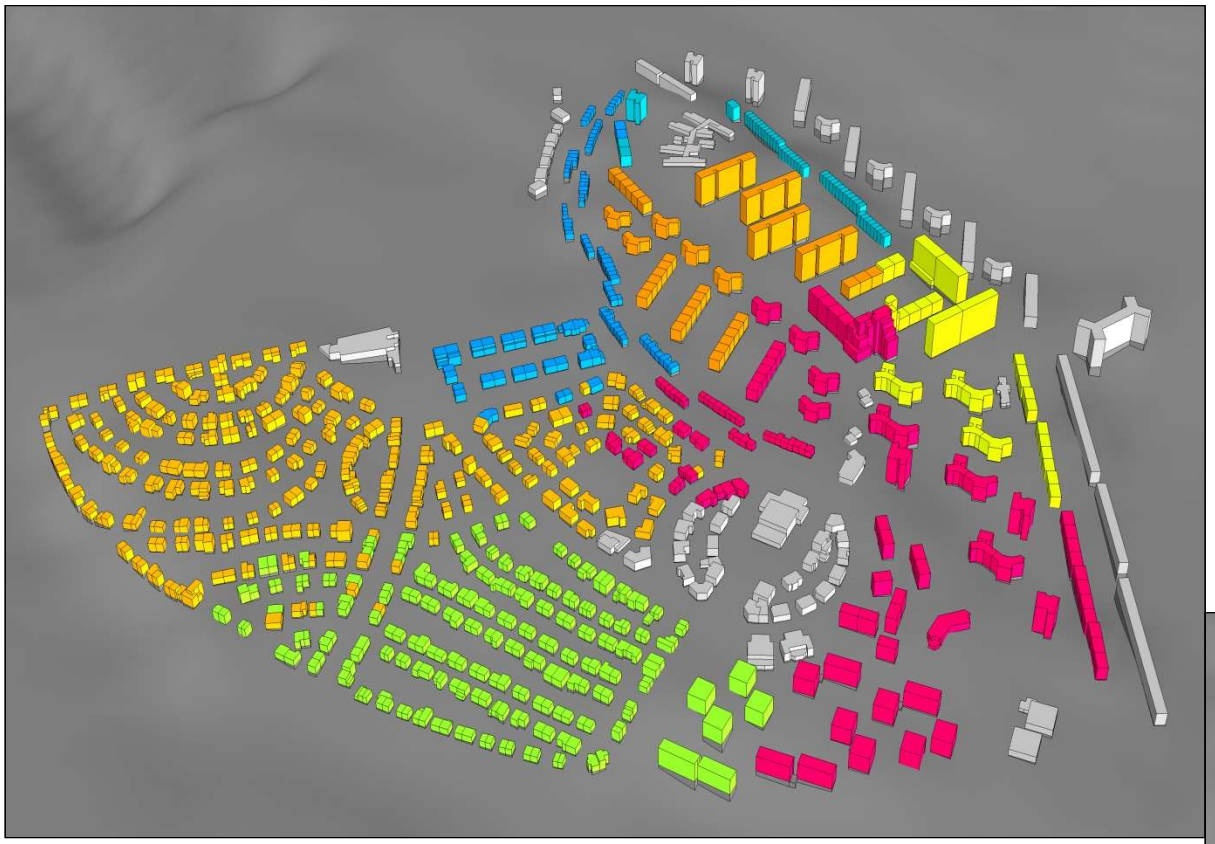
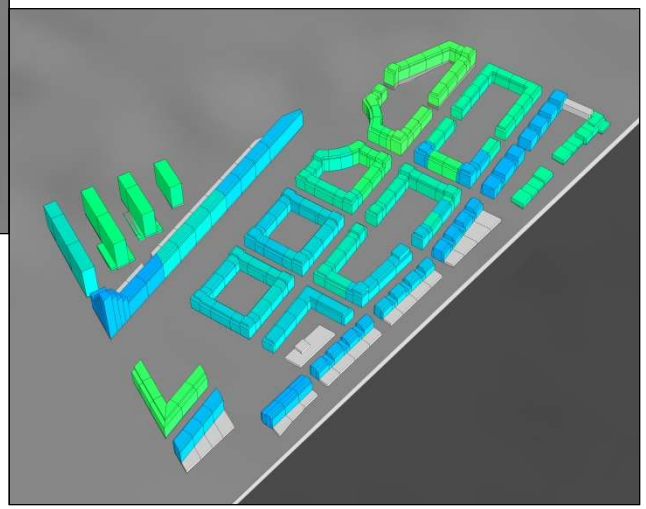
Energy savings by substation



100 *Daily Savings (kWh)* 1700

Olivais / Encarnacao

Cabo Ruivo



Each color represents the energy savings of all buildings connected to the same substation

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What about renewable generation?

SCENARIO 4

Solar Thermal Hot Water

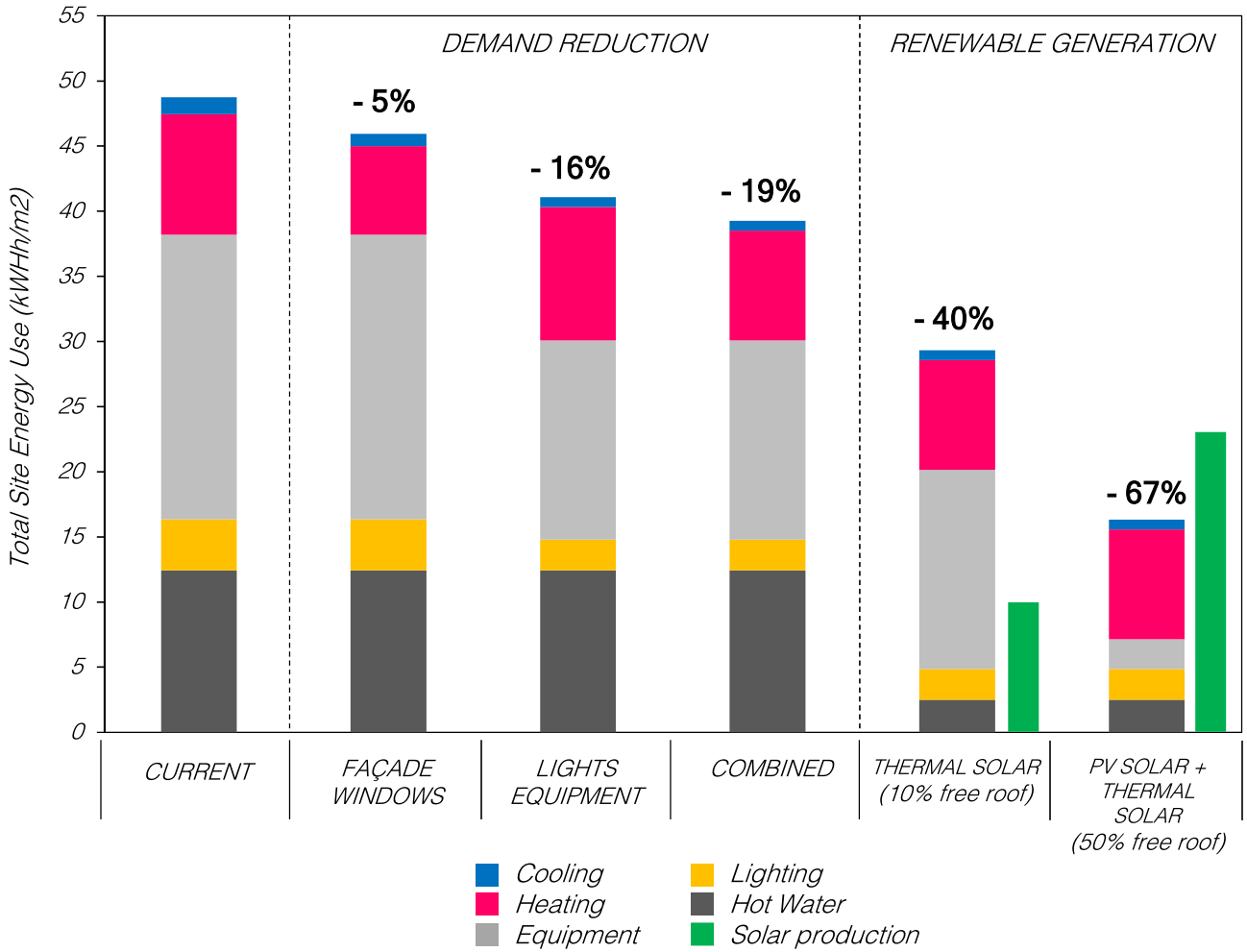
Evacuated tube solar thermal systems studied in all roofs. We assume collectors for 10% of exposed roof area, covering all hot water needs for 80% of situations in the year.

SCENARIO 5

Solar Thermal + Photovoltaic Panels

PV panels studied for exposed roofs in the case study neighborhoods, as an addition to solar thermal. They cover the remaining area required to achieve the 50% roof coverage requirement in the thermal code.

Aggregate potential savings



Average energy use by efficiency scenario

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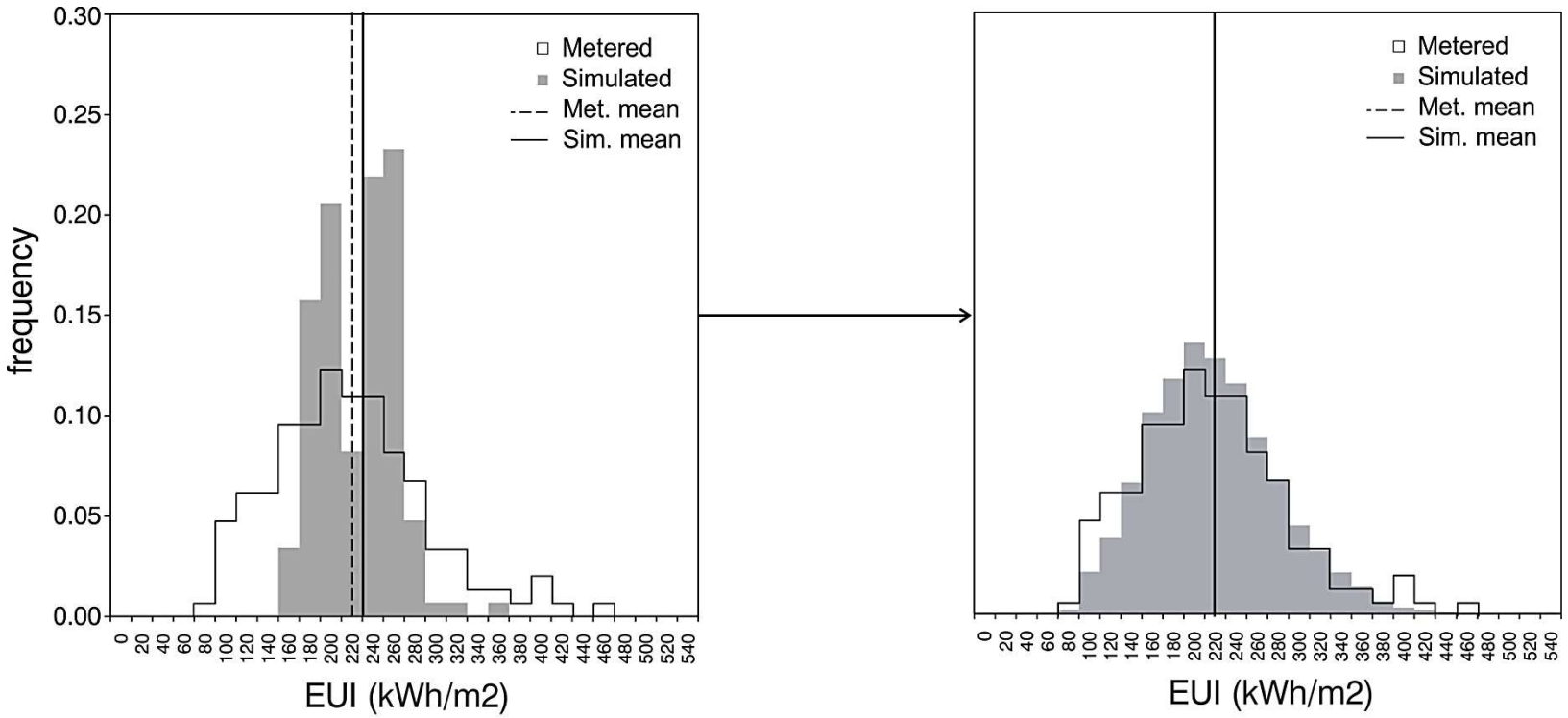
Occupant related parameters

The importance of modeling occupant diversity



Cerezo, Sokol, AlKhaled, Reinhart, AlMumin, Hajiah (2017) 'Comparison of four building archetype characterization methods in urban building energy modeling (UBEM): A residential case study in Kuwait City', Energy and Buildings 154, 321-354

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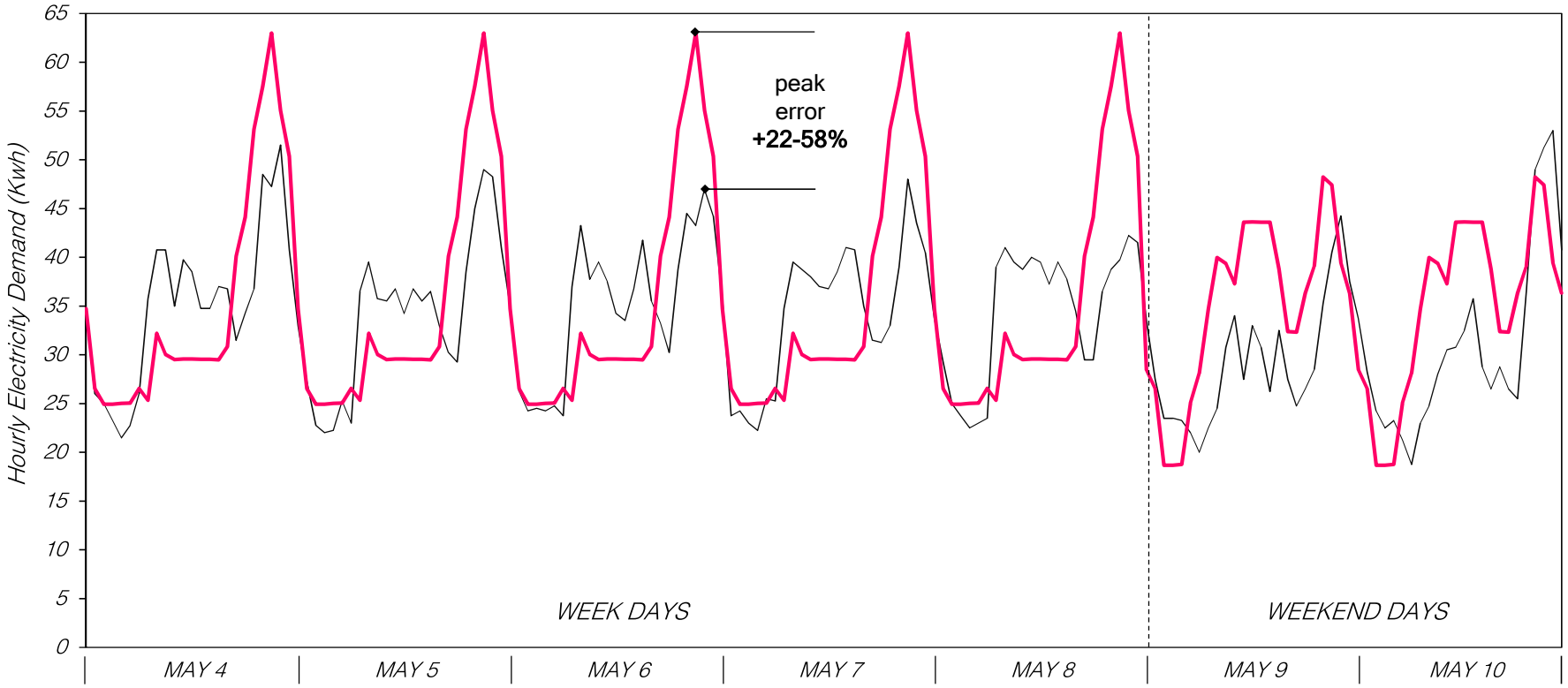
Difficulties at the hourly scale



Simulated VS metered hourly demands in substation PT8595 (Example week)

Metered substation data
Simulated using archetypes

Demand peaks exaggerated as a result of using only "typical schedules"

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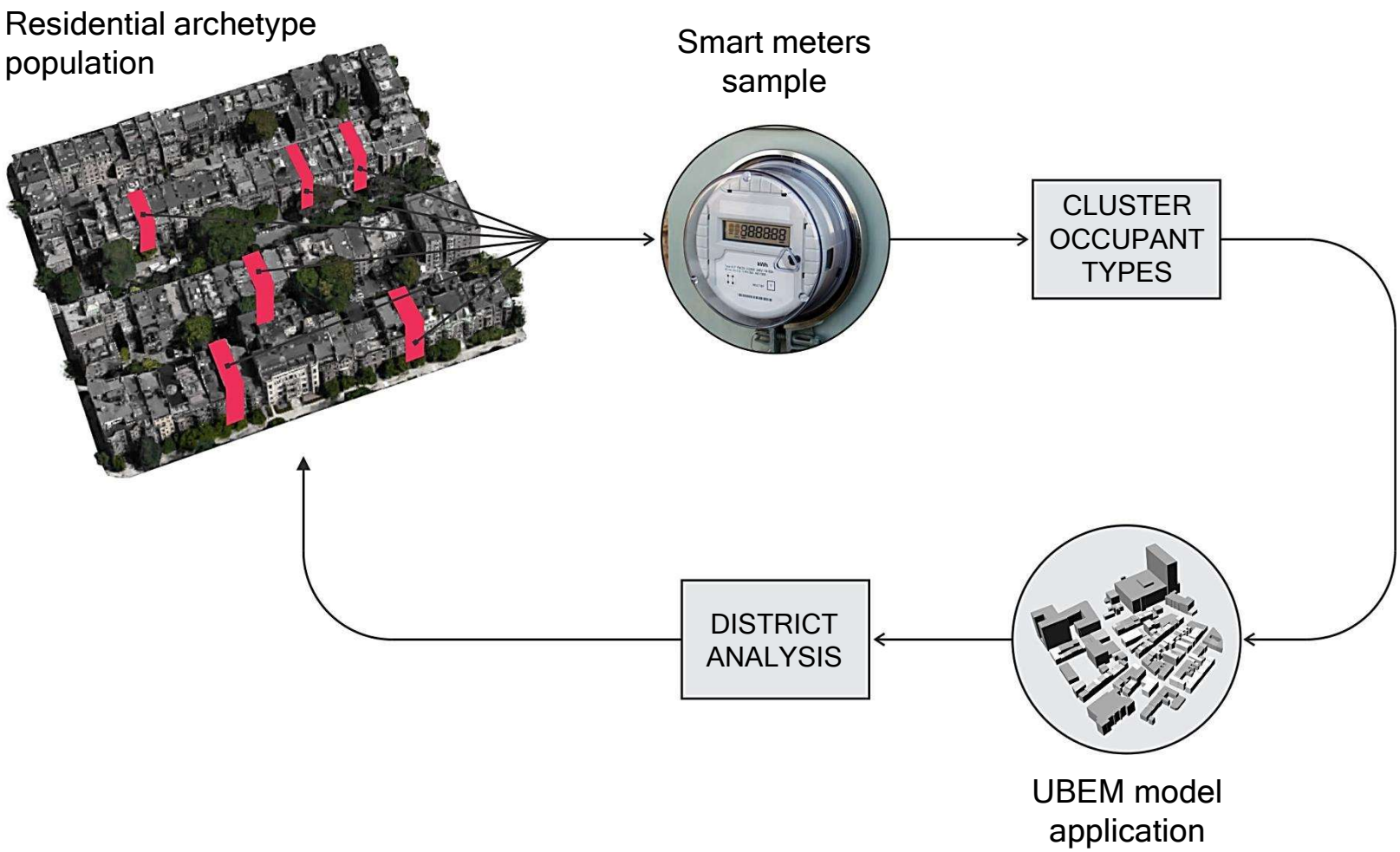
The potential of smart meter data



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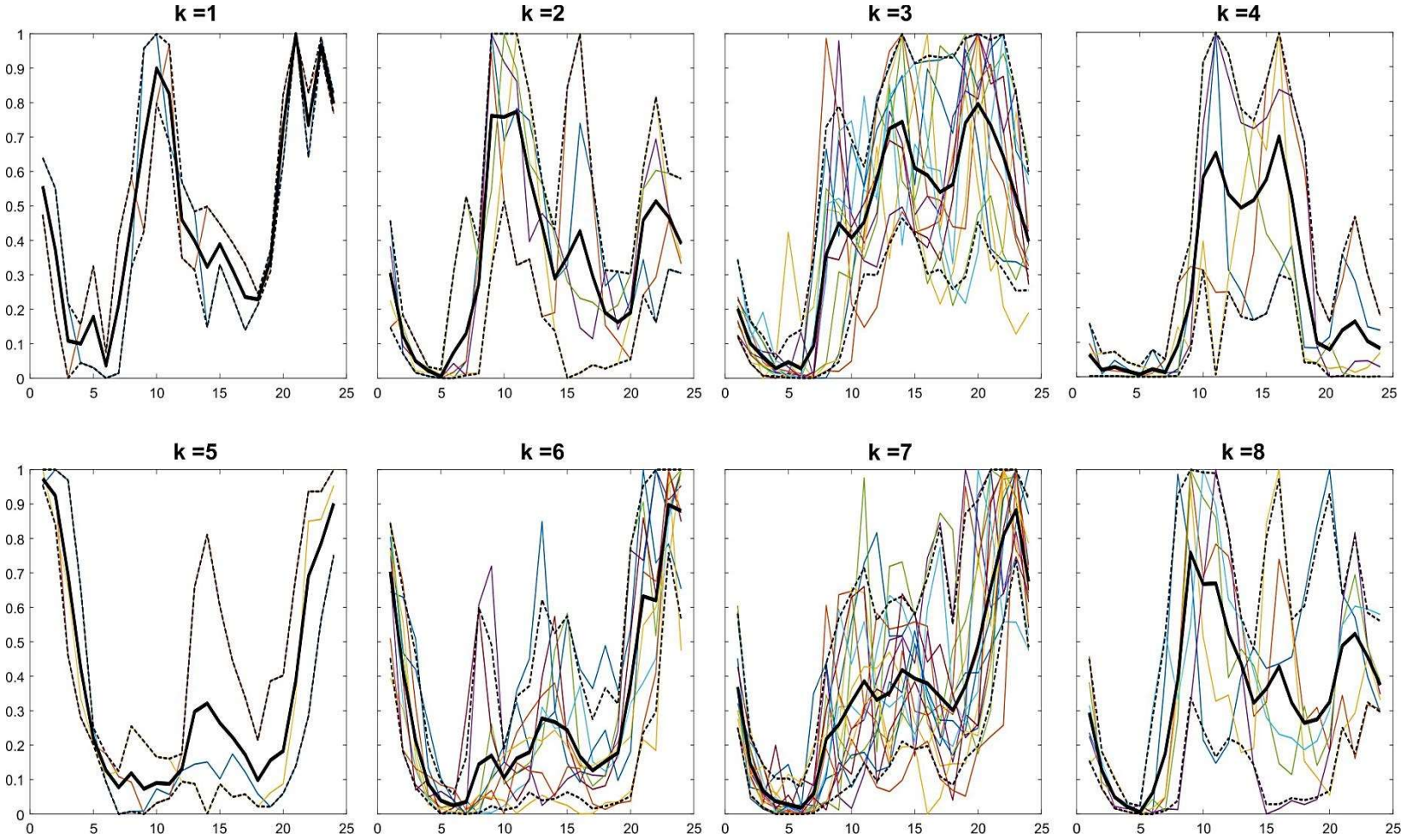
Clustering into occupant types



K-means clustering using 5 parameters / 8 clusters

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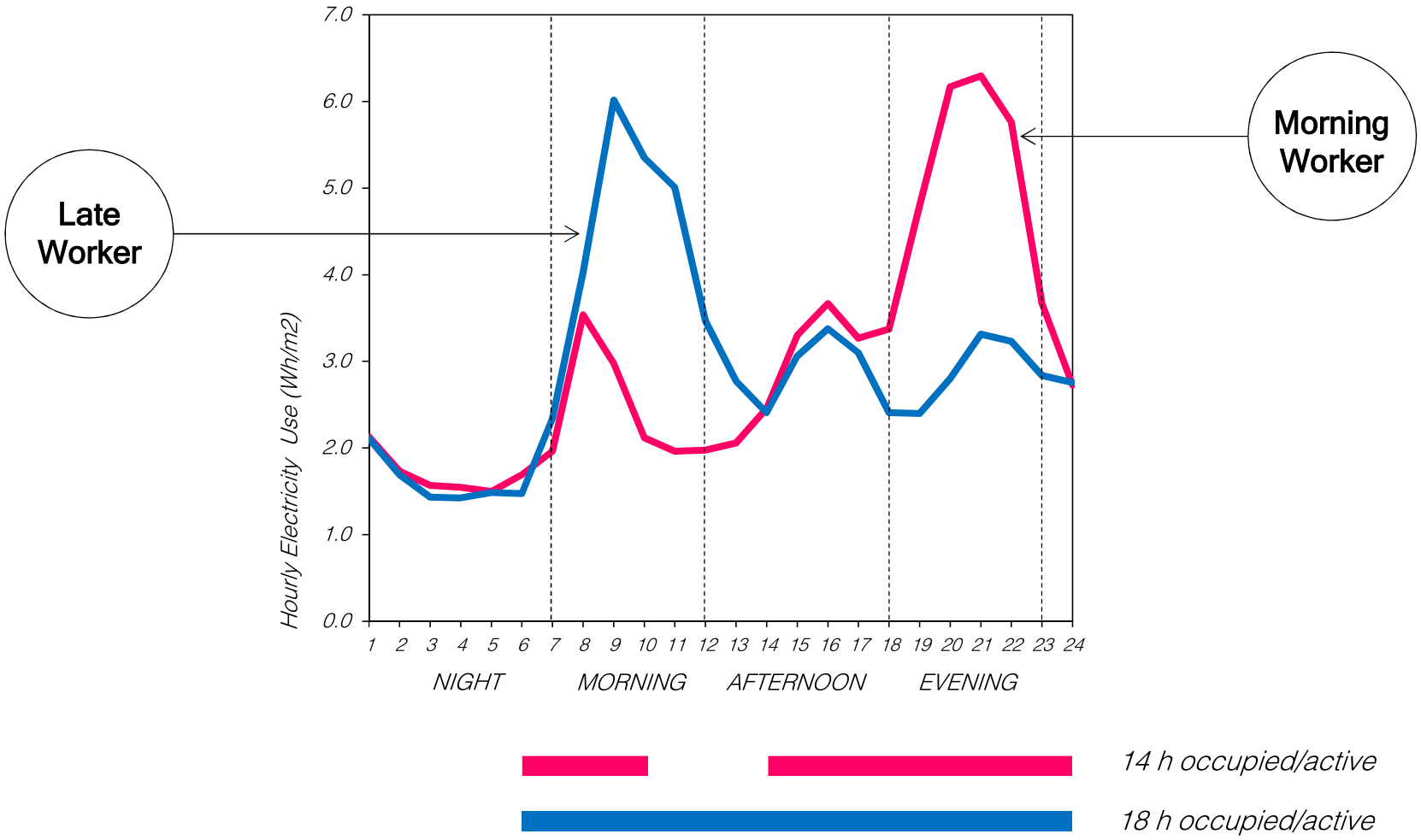
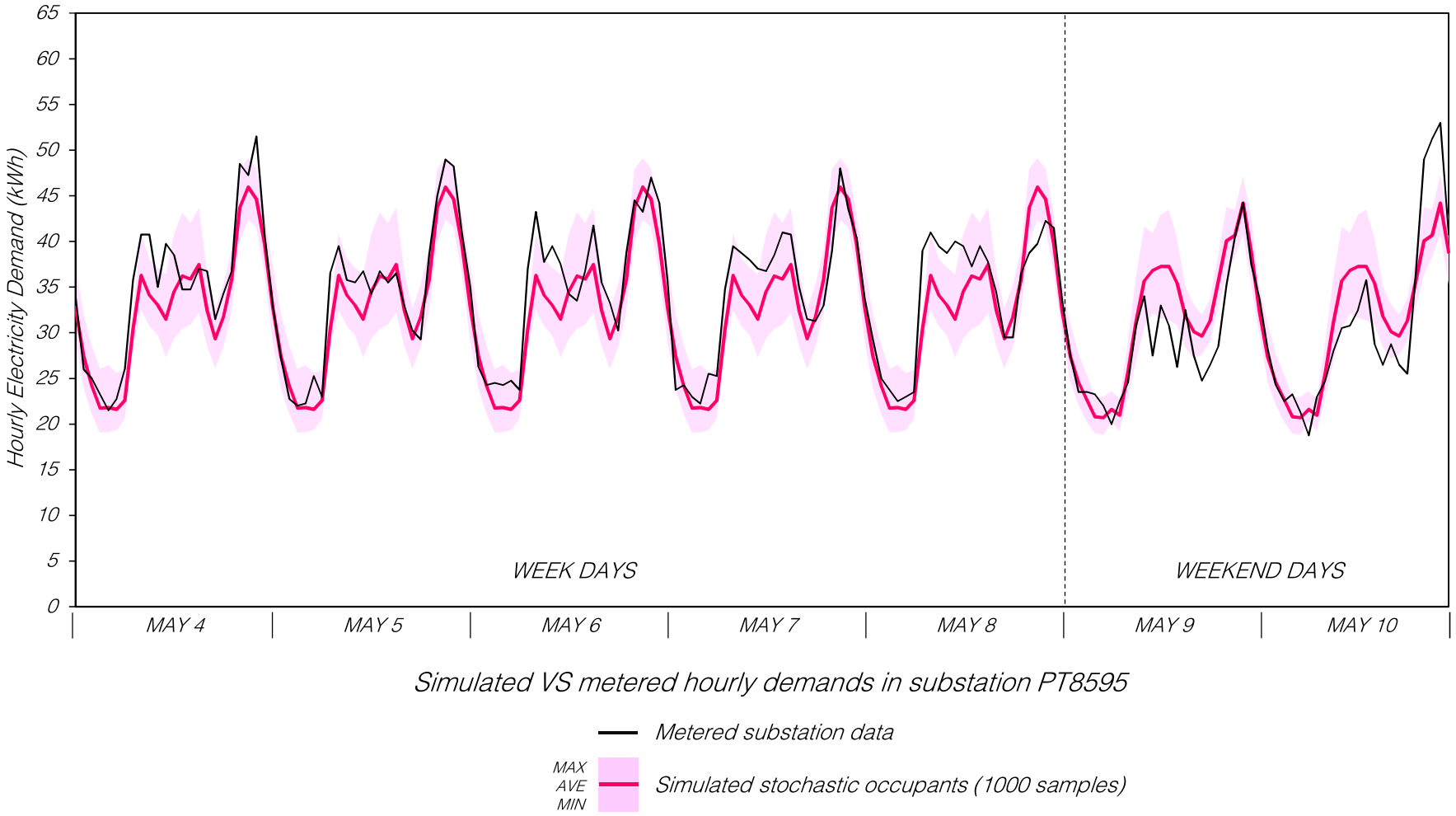
Example occupant type clusters



Substation modeling with occupant types



RMSE error reduced by 17% in weekdays and by 21% in weekends

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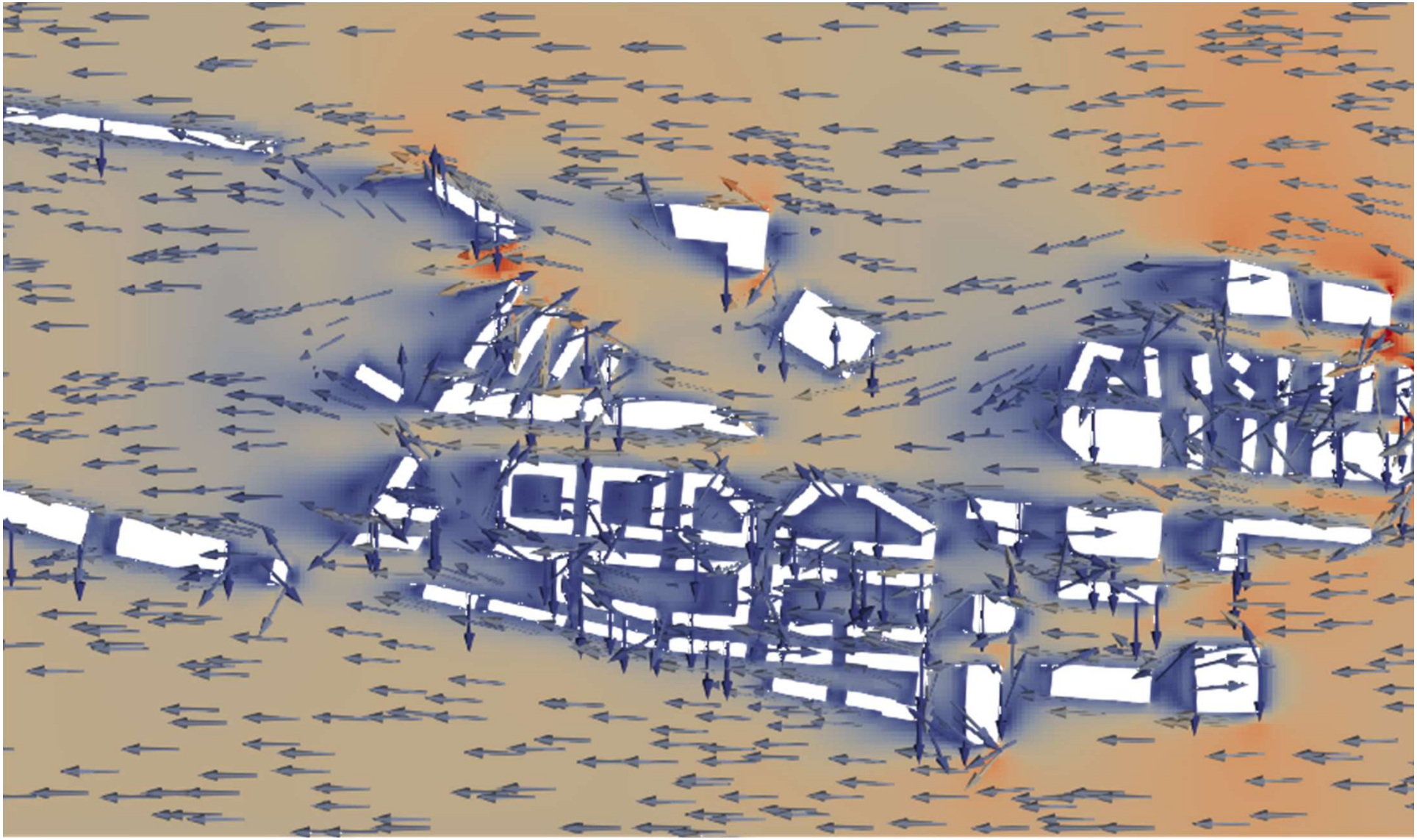
Some key ideas

- *Urban energy models (UBEMs) can effectively help policy makers to* **map and target energy efficiency strategies** *for buildings across a district.*

- *Lisbon's current residential building stock would benefit more from* **lighting and appliance upgrades**, *or* **solar energy systems**, *than from traditional envelope upgrades. Especially in structures built after the 1960s.*

- *For these strategies to effectively integrate with urban supply systems,* **smart metering systems** *should be deployed more extensively, to both improve analysis models and help understand occupant behavior.*



Natural Ventilation in a Warming Climate

Alpha Yacob Arsano/ MIT

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Natural ventilation in Lisbon

Motivation

Most buildings in Lisbon are naturally ventilated

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Current climate

Best climate in Lisbon: Majority of the year within the comfort range.

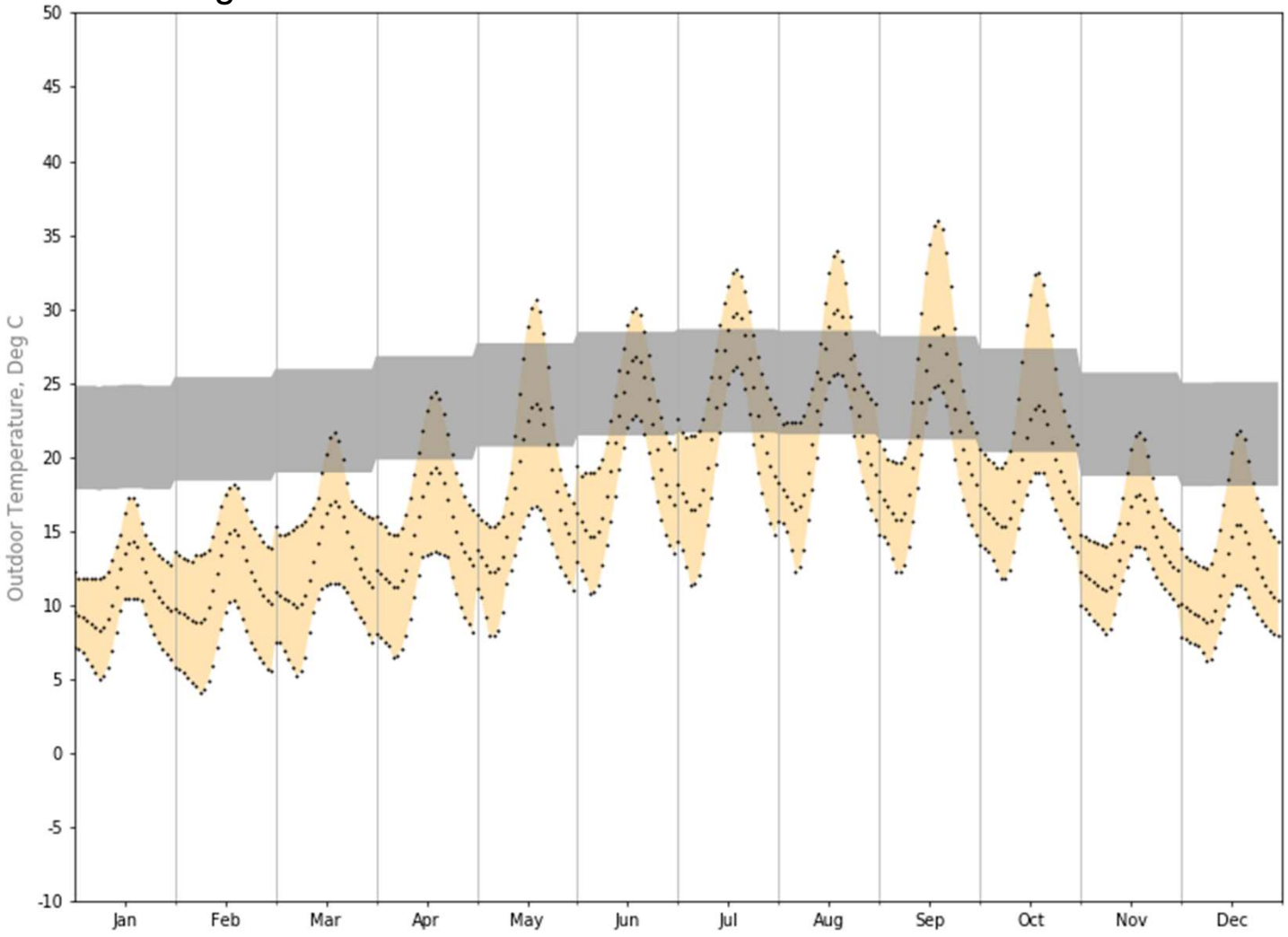

Chart generated using CLIMAPlus, an early design tool for the prediction of natural ventilation potential.
(Arsano, Reinhart, 2017)

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Future climate: 2080

Fast forward 2080: The climate will get warmer due to climate change.

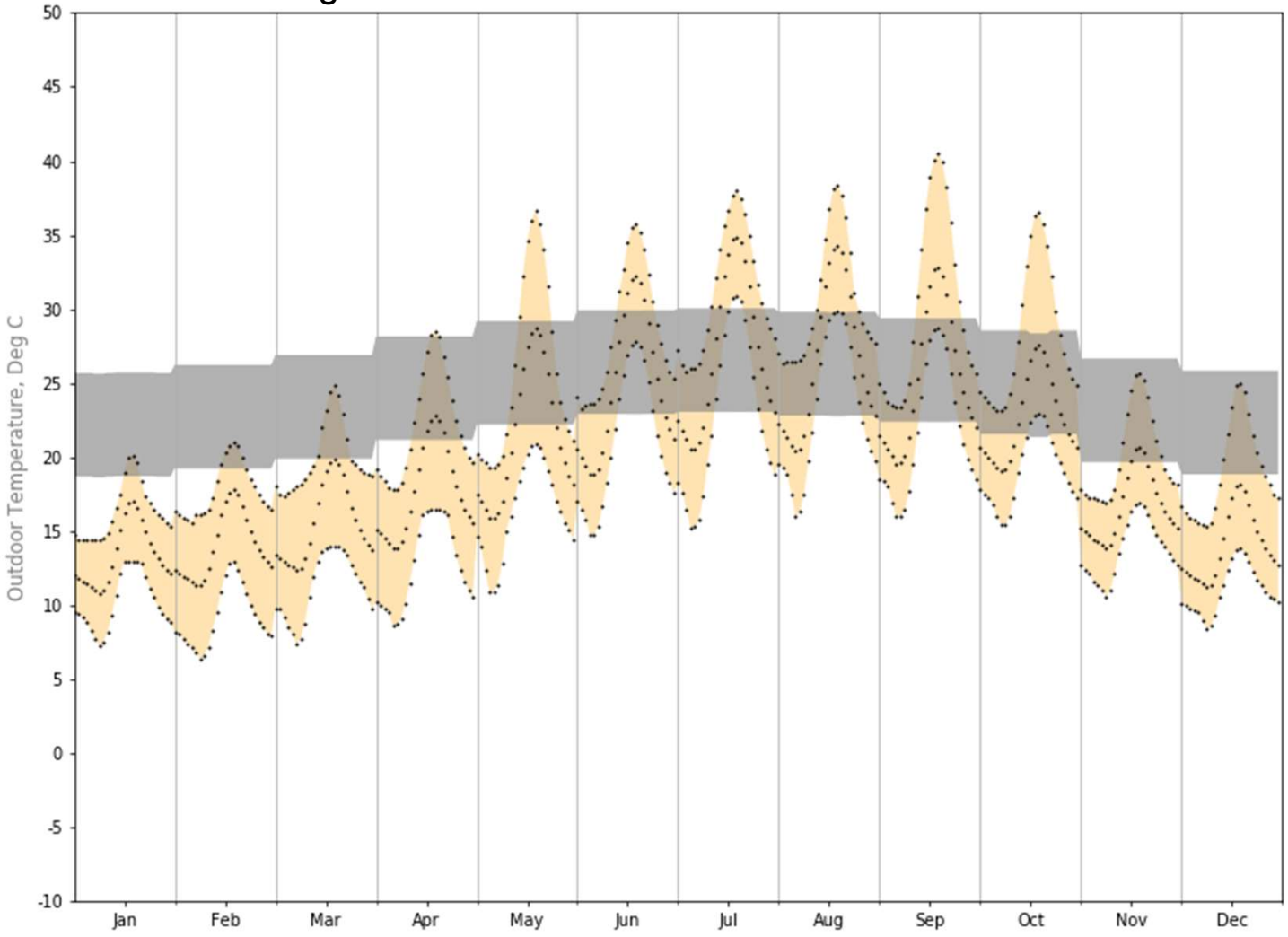

Chart generated using CLIMAPlus, an early design tool for the prediction of natural ventilation potential.
(Arsano, Reinhart, 2017)

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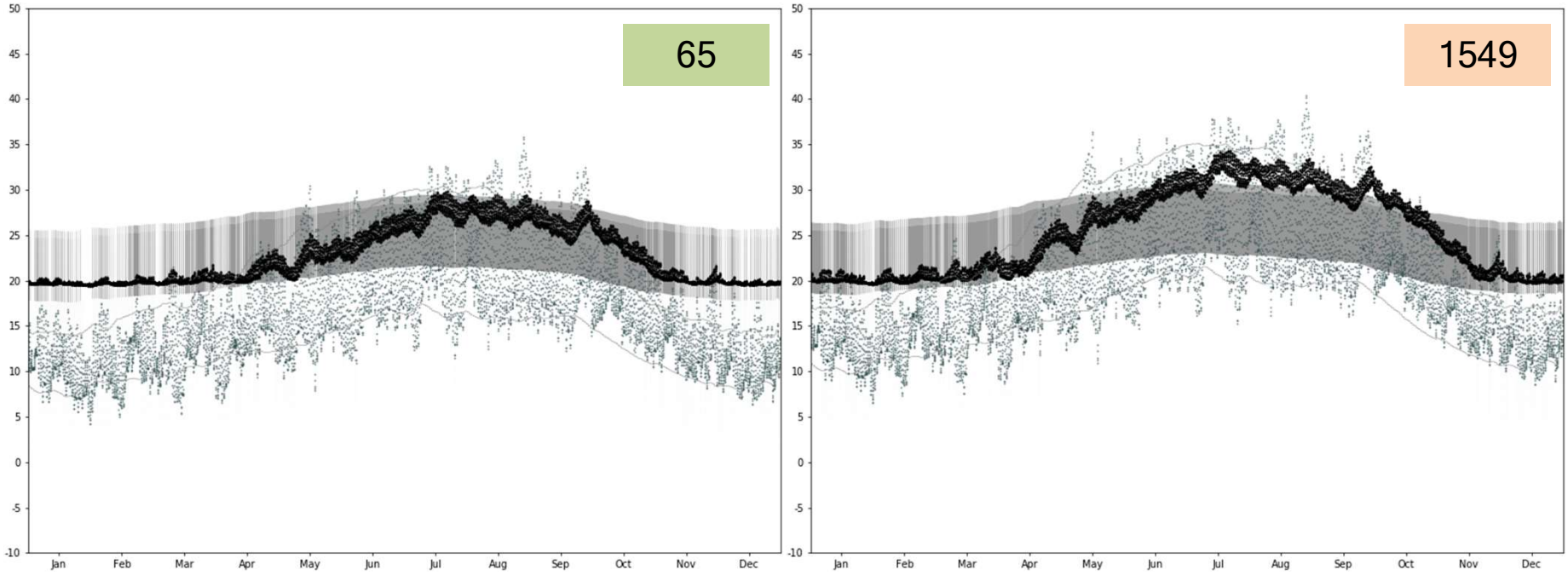
Thermal comfort now and in 2080

Current

High natural ventilation potential. Thermal comfort is maintained all year round.

2080

Reduced natural ventilation potential. Number of discomfort hours will go over 1500.



Climate box simulation for a residence unit

Charts generated using CLIMAPlus, an early design tool for the prediction of natural ventilation potential.
(Arsano, Reinhart, 2017)

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Proposed solution

2080: Maximized natural ventilation potential combined with air conditioning

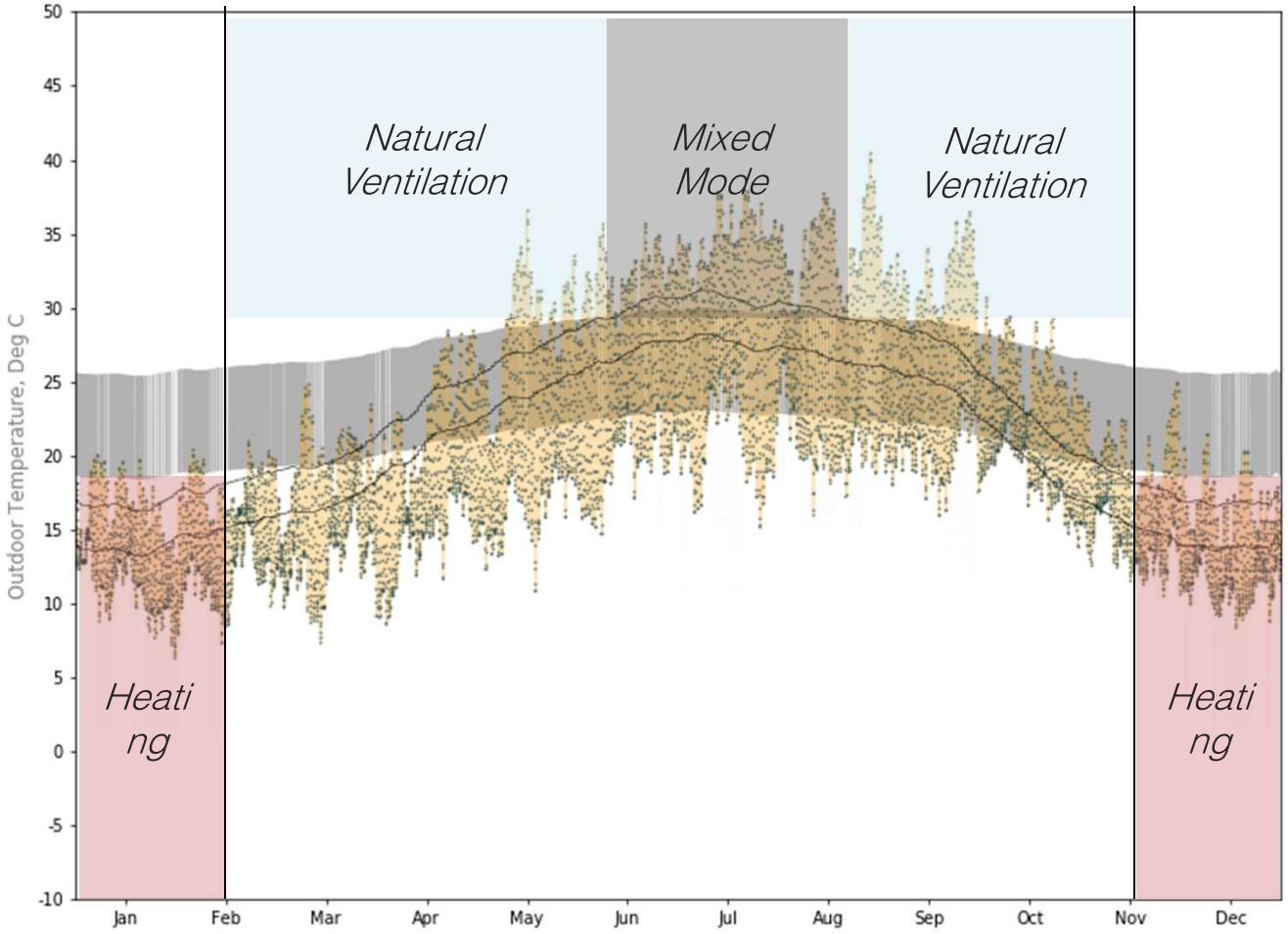

Chart generated using CLIMAPlus, an early design tool for the prediction of natural ventilation potential.
(Arsano, Reinhart, 2017)

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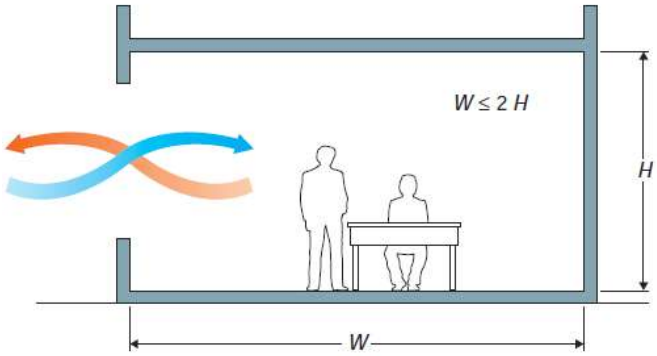
Natural ventilation forces

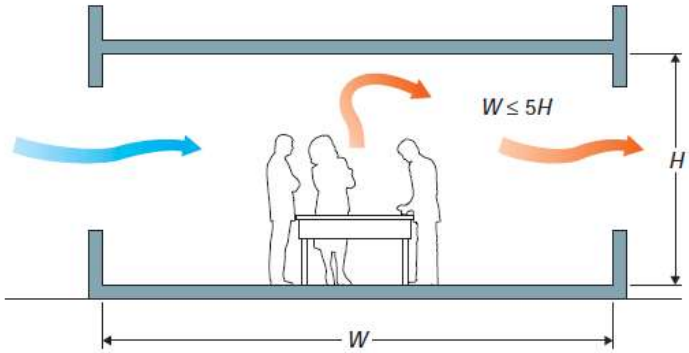
New approach to combine the two forces of natural ventilation at a **neighborhood** level.

Buoyancy ventilation



Flow is determined based on indoor and outdoor air temperature difference.

Wind ventilation



Flow is determined based on wind pressures acting on the building facades.

Natural ventilation in Lisbon's neighborhood

Cabo Ruivo

139 buildings
92% Period 5
8% Period 6

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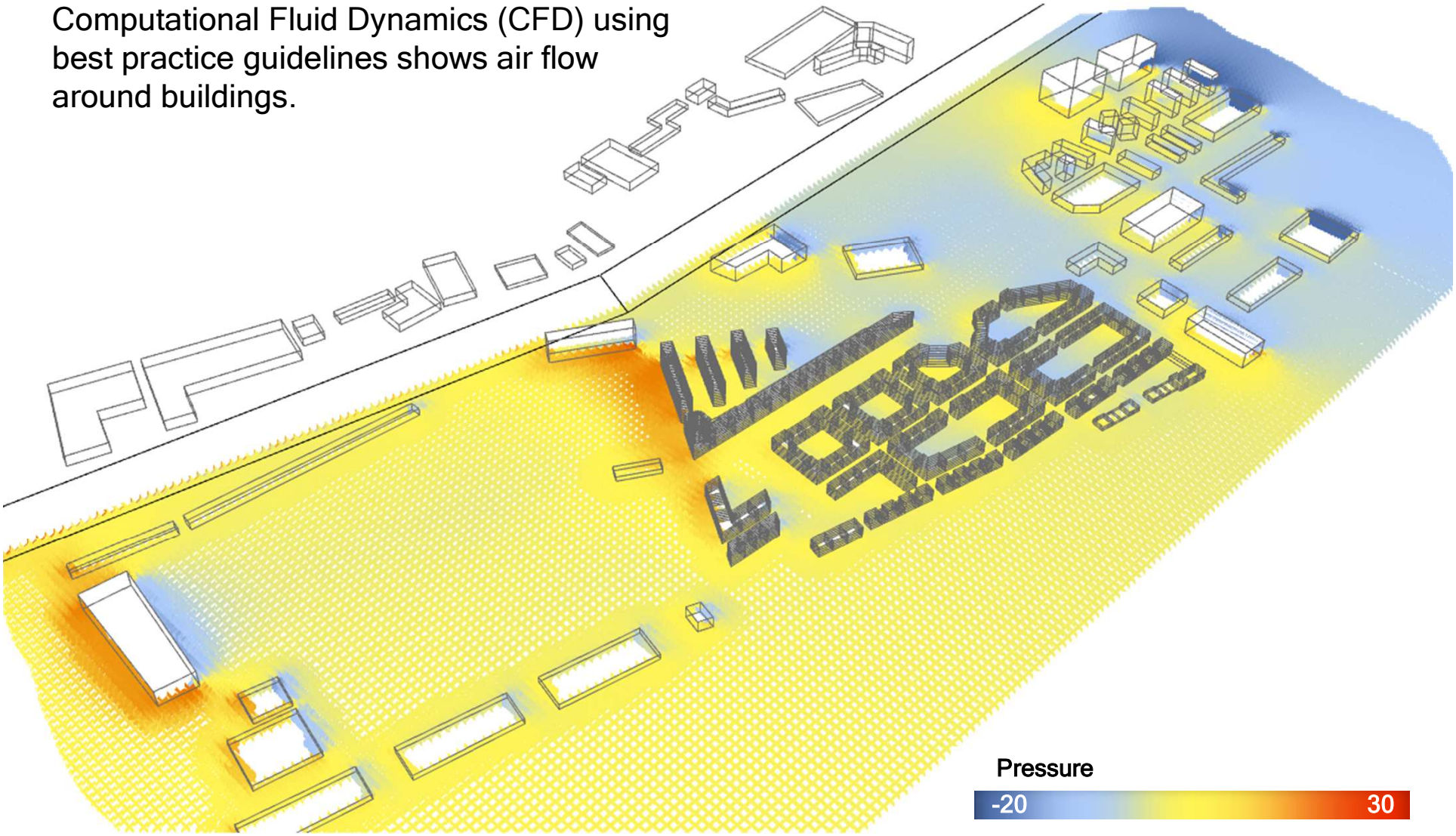
Wind flow around buildings

Computational Fluid Dynamics (CFD) using best practice guidelines shows air flow around buildings.



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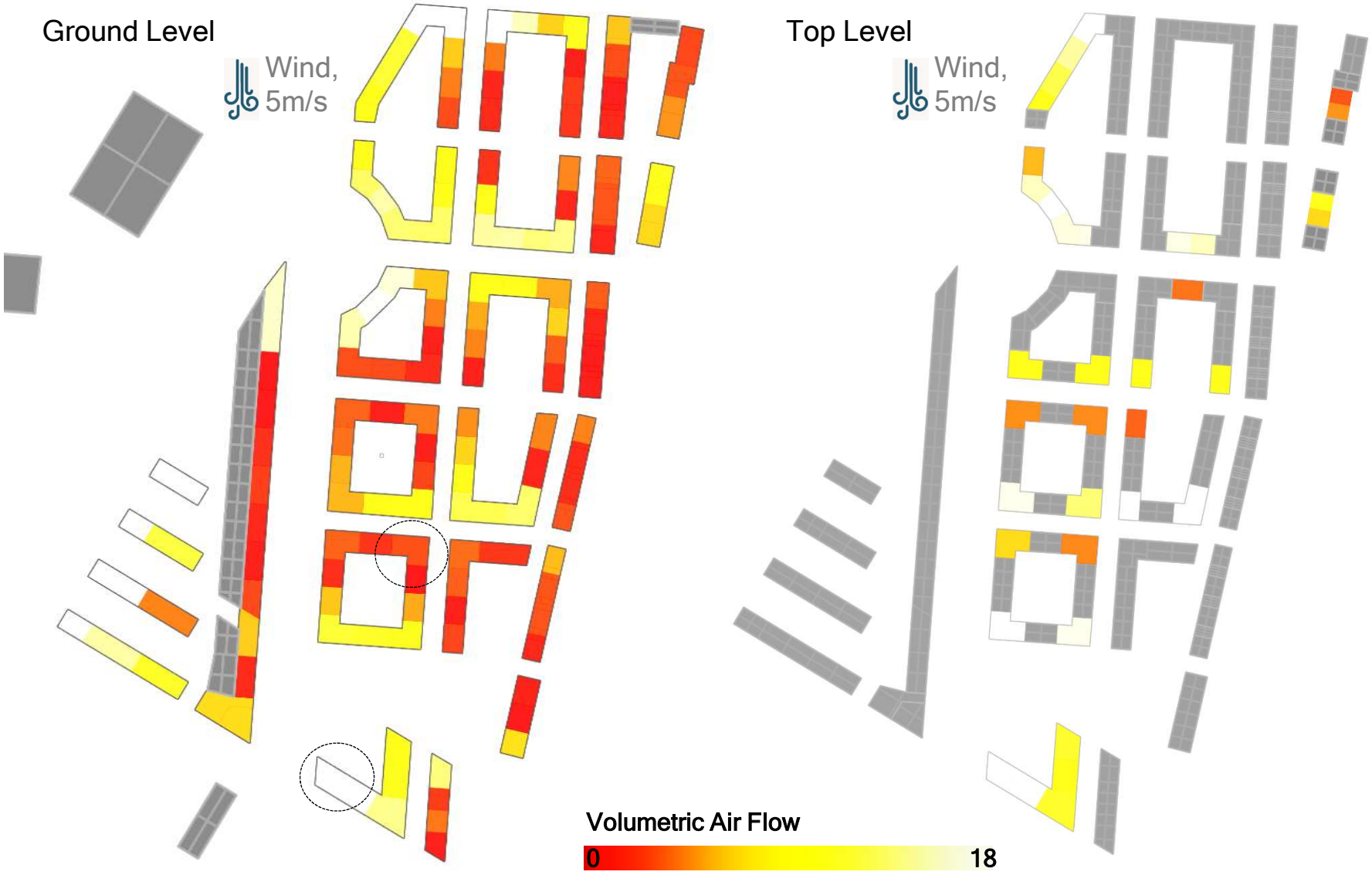
Wind driven ventilation in buildings



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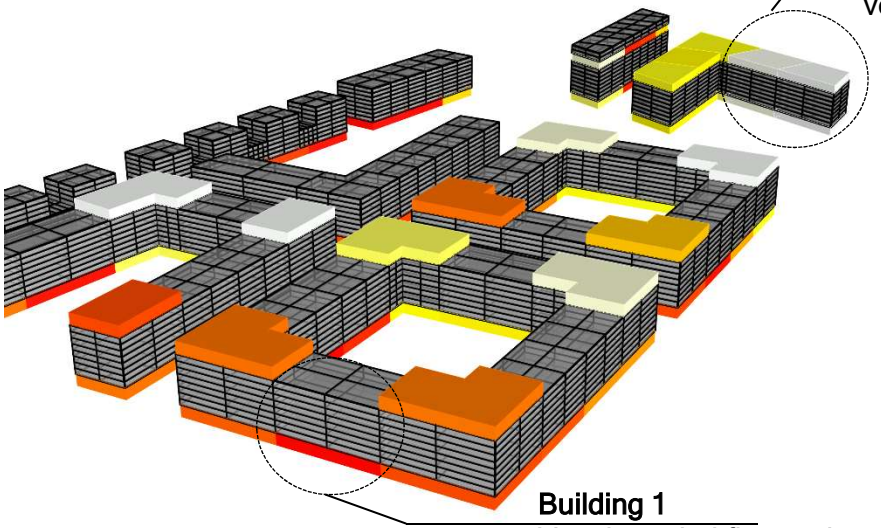
Results

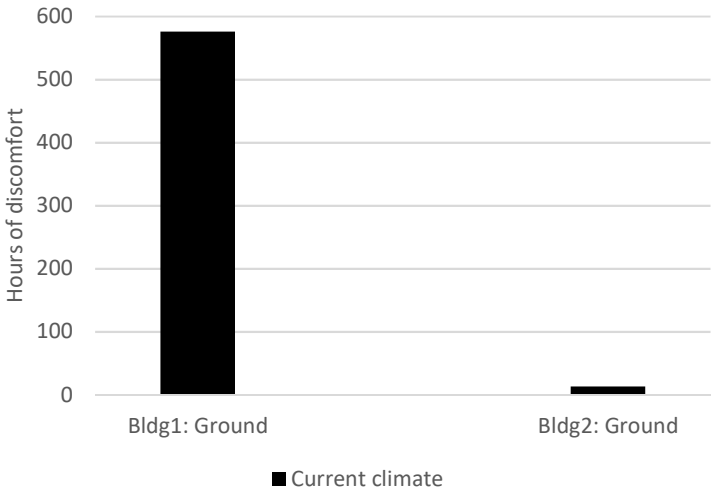
Current climate: Acceptable thermal comfort in buildings is achieved with natural ventilation.

Thermal comfort study is based on building performance simulations using inputs from wind flow study.



Building 2
High wind flow to the building and it is comfortable all year round with natural ventilation.

Building 1
Very low wind flow at the ground level. The number of hours with high temperature are greater than building 2.



Volumetric Air Flow

0 — 18

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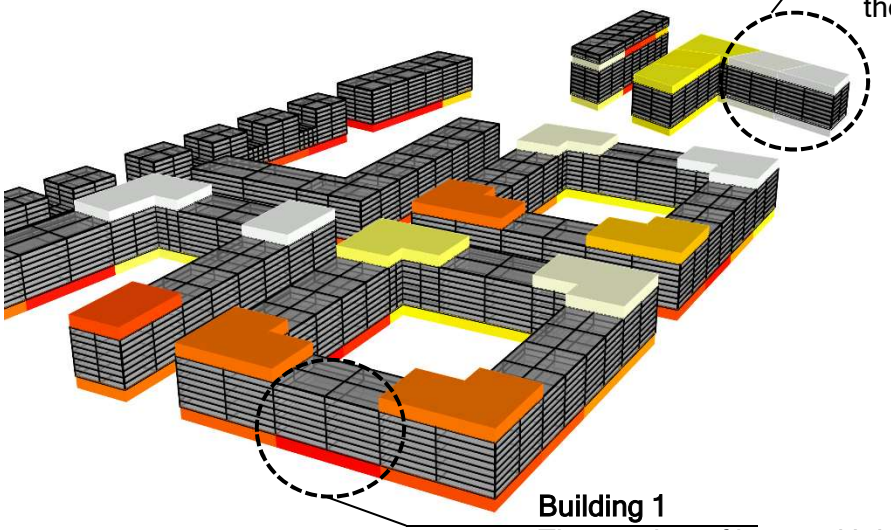
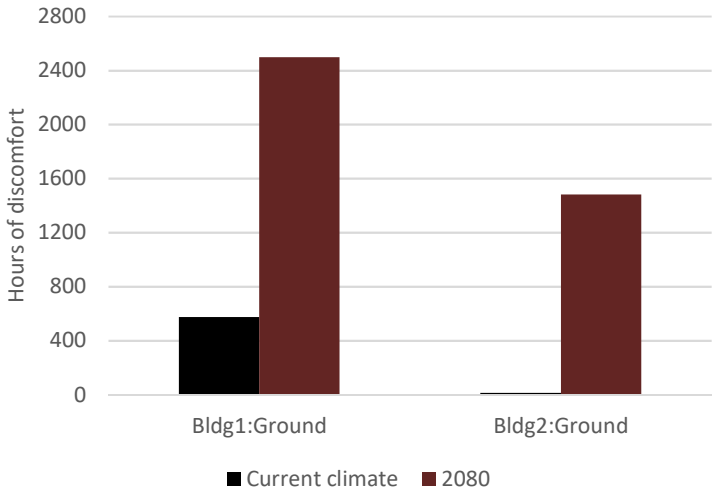
Results

Current and 2080 climate comparison:
Thermal comfort that can be achieved in *Building 1* in 2080 with only natural ventilation will be low. Cooling will be required.



Building 2
It is comfortable all year round with natural ventilation in current climate, however thermal comfort will be lower in 2080.

Building 1
The number of hours with high temperature will be greater than Building-2 in 2080.



Volumetric Air Flow

0 18

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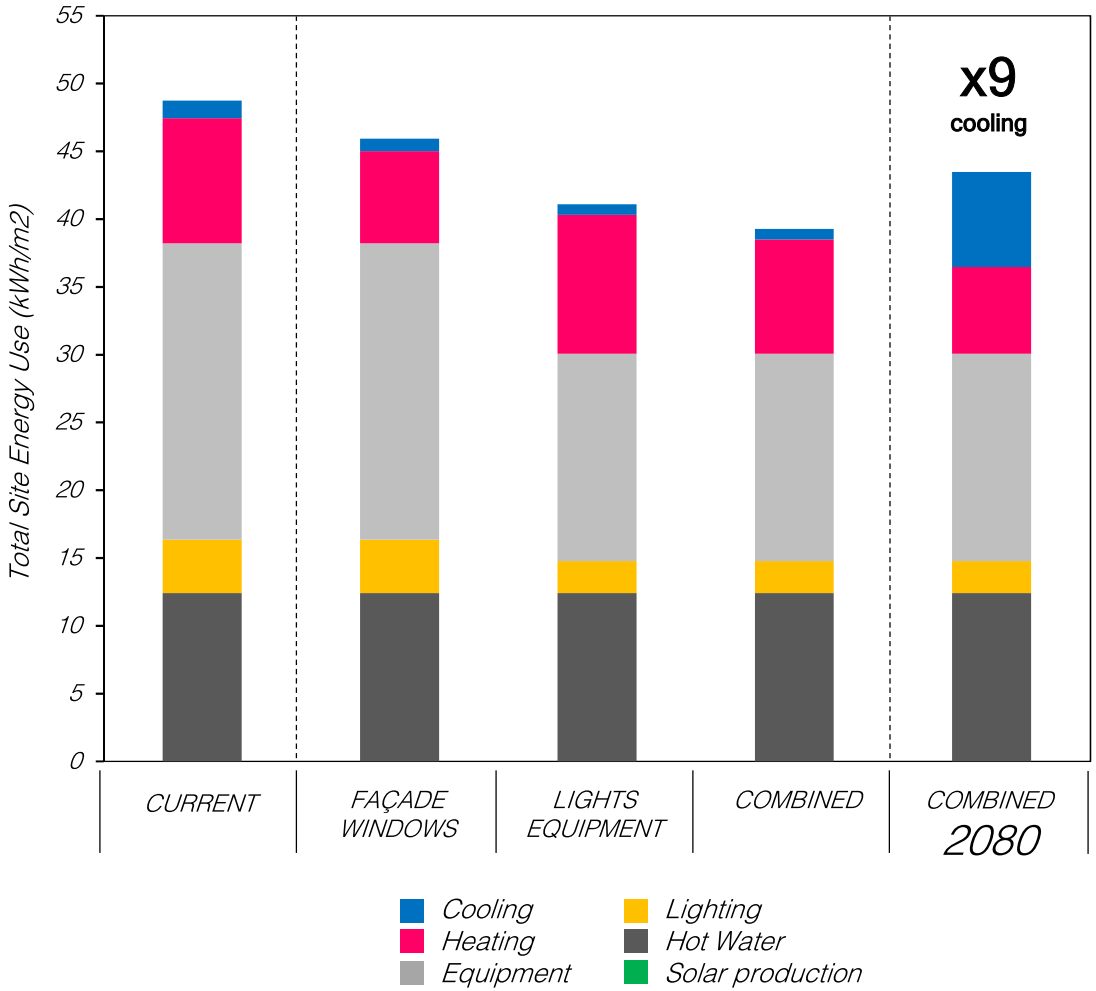
Increase in cooling loads in 2080



Average energy use by efficiency scenario

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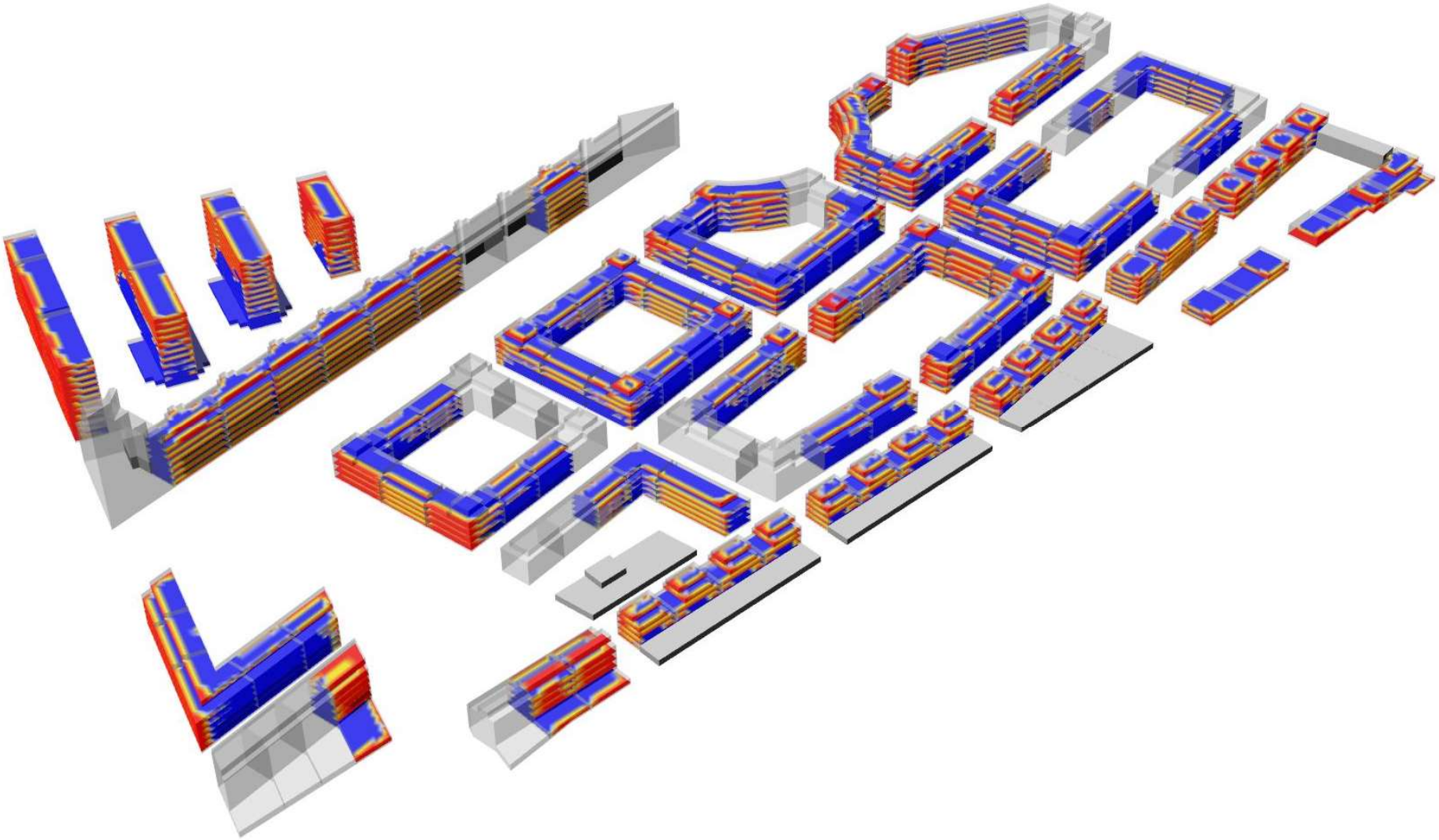
Some key ideas

- Neighborhood design influences performance of buildings. The density and orientation of buildings regulate flow of air from wind ventilation.

- Lisbon will be warmer under climate change. A hybrid system of natural ventilation and cooling is required to reduce public health risks.



The Value of Daylight (in PT Property Tax)

Irmak Turan / MIT

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Quality of Indoor Spaces

Can Lis (Mallorca 1971)

Vanderbilt towards 42nd St (NYC 1930s)

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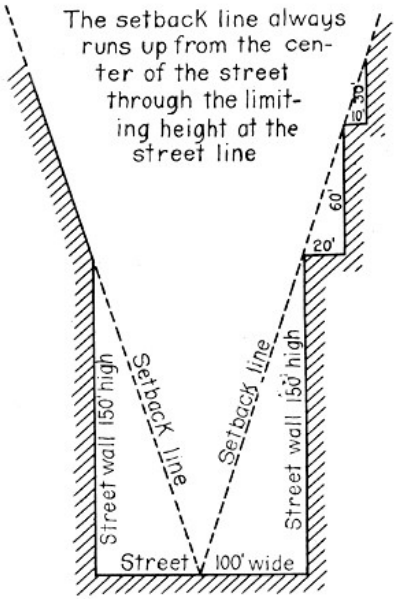
Protecting Design Quality through Planning

REFERENCE FRAME TO STAY WITHIN

CODES

NYC's Zoning Regulation of 1916



-vs-

TAXES

UK's "Window Tax" (1696-1851)

NYC (1916) 'Zoning resolution' / Hugh Ferriss (1929) 'The metropolis of tomorrow'
By Whilesteps - Own work by uploader Gary Burt (myspace/slowsmile), CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=4406259

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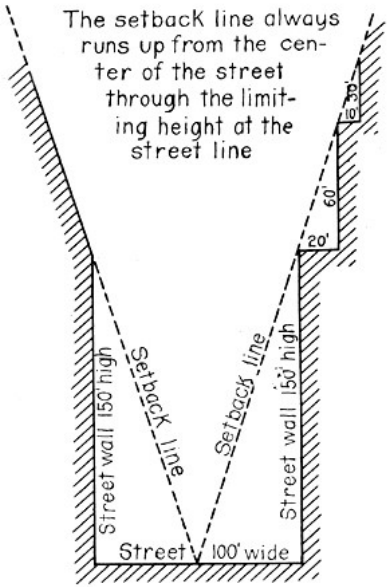
Protecting Design Quality through Planning

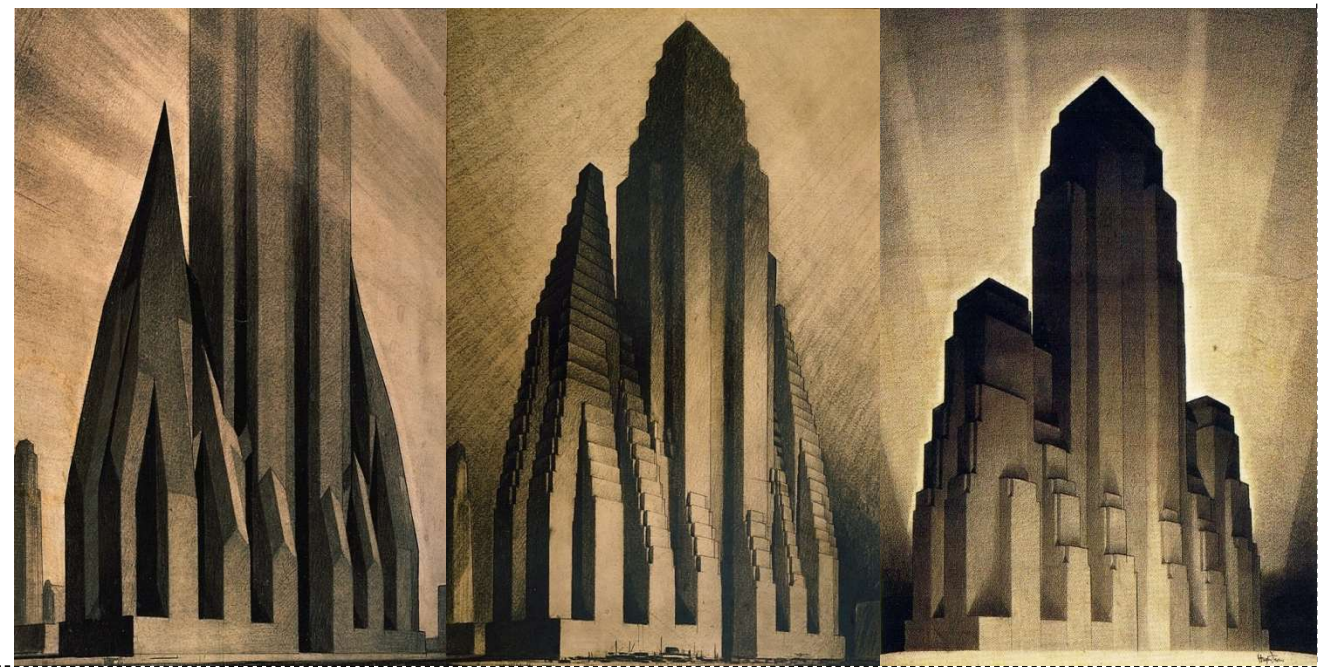
REFERENCE FRAME TO STAY WITHIN

ZONING

Access to light requirements appear in housing acts and bylaws at the end 19th century, as a result of industrial city conditions.

Setback rules are introduced in the NYC Zoning Regulation of 1916 to guarantee sunlight access. Regulation becomes three dimensional.





NYC (1916) 'Zoning resolution' / Hugh Ferriss (1929) 'The metropolis of tomorrow'

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Urban zoning application

Saratsis, Dogan, Reinhart, (2017) 'A simulation-based daylighting analysis procedure for the development of urban zoning rules' Building Research and Information 245-5

Protecting Design Quality through Planning

TAXING

The UK's "Window Tax": A variable tax based on the number of windows in the house above ten windows.

We are obliged to pay for what nature lavishly supplies to all, at so much per window per year; and the poor who cannot afford the expense are stinted in two of the most urgent necessities of life.

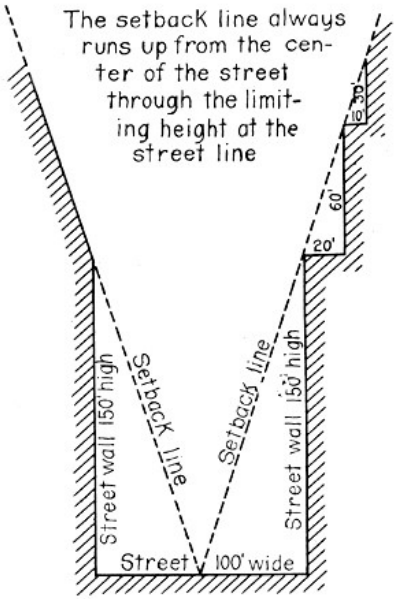
Charles Dickens
Household Words, 1850

images: By Whilesteps - Own work by uploader Gary Burt (myspace/slowsmile), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4406259
Glantz, A. E. (2008) 'A Tax on Light and Air: Impact of the Window Duty on Tax Administration and Architecture, 1696-1851', Penn History Review, 15(2), pp. 18–23.
Oates, W. E. and Schwab, R. M. (2015) 'The Window Tax: A Case Study in Excess Burden', *Journal of Economic Perspectives*, 29(1), pp. 163–180. doi: 10.1257/jep.29.1.163.

Protecting Design Quality through Planning

CODES

NYC's Zoning Regulation of 1916



-vs-

How about in Portugal?

TAXES

UK's "Window Tax" (1696-1851)

NYC (1916) 'Zoning resolution' / Hugh Ferriss (1929) 'The metropolis of tomorrow'
By Whilesteps - Own work by uploader Gary Burt (myspace/slowsmile), CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=4406259

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IMI (Imposto Municipal sobre Imóveis)

Jornal de Notícias

EPAPER | NEWSLET

Pesquisar

JN Direto | Nacional | Local | Justiça | Mundo | Economia | Desporto | Pessoas | Inovação | Artes/Etc | Opinião

Habitação

Boa exposição solar e terraço podem agravar IMI

01 Agosto 2016 às 19:34

COMENTAR

TÓPICOS
IMI
Economia

Foto: Pedro Granadeiro/Global Imagens

O IMI pode subir ou descer consoante a exposição solar ou a qualidade ambiental da habitação, segundo um diploma publicado em Diário da República.

Segundo o diploma, publicado esta segunda-feira, aumenta a variação máxima prevista para o coeficiente de 'localização e operacionalidade relativas.

O decreto-lei n.º41/2016, publicado hoje, introduz uma alteração ao Código do Imposto Municipal sobre Imóveis (IMI), no coeficiente de 'localização e operacionalidade relativas', um dos elementos que influencia (aumentando ou diminuindo) o coeficiente de qualidade e conforto, que é tido em conta no cálculo do valor patrimonial tributário, base à qual é aplicada a taxa de IMI.

IMI updated in 2016 to account for sun exposure, views, terraces, etc...

https://www.jn.pt/economia/interior/boa-exposicao-solar-e-terraco-podem-agravar-imi-5317046.html

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Portuguese Residential Property Tax

IMI (Imposto Municipal sobre Imóveis)

Updated in 2016 to include a component for light in the house, under the quality and comfort coefficient:

$$Vt = Vc * A * Ca * Cl * Cq * Cv$$

Vt	valor patrimonial tributário	taxable net worth
Vc	valor base dos prédios edificados	base value
A	área bruta de construção mais a área excedente à área de implantação	built area + free plot area
Ca	coeficiente de afectação	use coefficient
Cl	coeficiente de localização	location coefficient
Cq	coeficiente de qualidade e conforto	quality and comfort coefficient
Cv	coeficiente de vetustez	age coefficient

*Note: The tax only applies to new buildings or IMI re-evaluations.

UWU Solutions (2016) *IMI - Learn about the new rules*. Available at: https://uwu.pt/a/index.php/en/uwu-news/learn-about-the-new-rules (Accessed: 8 March 2018).
Directorate General for Taxation (2009) *The Portuguese Tax System*, *Taxation*. Lisbon.

Portuguese Residential Property Tax

Factors that impact quality and comfort coefficient

Elementos de qualidade e conforto	Coeficientes
Majorativos:	
Moradias unifamiliares	Até 0,20
Localização em condomínio fechado	0,20
Garagem individual	0,04
Garagem coletiva	0,03
Piscina individual	0,06
Piscina coletiva	0,03
Campos de ténis	0,03
Outros equipamentos de lazer	0,04
Qualidade construtiva	Até 0,15
Localização excecional	Até 0,10
Sistema central de climatização	0,03
Elevadores em edifícios de menos de quatro pisos	0,02
Localização e operacionalidade relativas	Até 0,20
Minorativos:	
Inexistência de cozinha	0,10
Inexistência de instalações sanitárias	0,10
Inexistência de rede pública ou privada de água	0,08
Inexistência de rede pública ou privada de electricidade	0,10
Inexistência de rede pública ou privada de gás	0,02
Inexistência de rede pública ou privada de esgotos	0,05
Inexistência de ruas pavimentadas	0,03
Inexistência de elevador em edifícios com mais de três pisos	0,02
Existência de áreas inferiores às regulamentares	0,05
Estado deficiente de conservação	Até 0,05
Localização e operacionalidade relativas	Até 0,10

(Redação do Decreto-Lei n.º 41/2016, de 01/08)

Localizaçao e Operacionalidade Relativas component can vary Cq from -10% to +20%.

https://zonamentopf.portaldasfinancas.gov.pt/simulador/default.jsp

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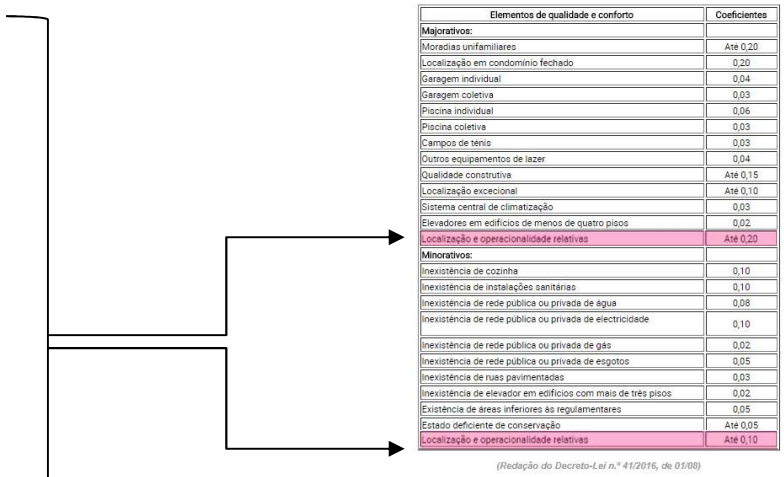
Portuguese Residential Property Tax

Qualidade construtiva:

- Qualidade do projecto;
- Ventilação — sistemas de aquecimento e arrefecimento;
- Isolamento térmico;
- Conforto acústico;
- Nível de qualidade dos revestimentos/acabamentos;
- Nível de qualidade/existência de instalações especiais — segurança, incêndio, domótica;

Localização excepcional:

- Vistas panorâmicas;
- Orientação da construção;
- Piso;
- Enquadramento urbanístico — equipamentos colectivos, densidade de construção;
- Qualidade ambiental — zonas verdes, elementos naturais, ausência de poluição;
- Estado de deficiente conservação: Anomalias na estrutura;
- Cobertura em mau estado;
- Revestimentos de piso, paredes e tectos deteriorados;
- Caixilharia deteriorada;
- Instalações deterioradas ou em deficiente funcionamento;
- Condições de salubridade e higiene deficientes.



Elementos de qualidade e conforto	Coeficientes
Majorativos:	
Moradias unifamiliares	Até 0,20
Localização em condomínio fechado	0,20
Garagem individual	0,04
Garagem coletiva	0,03
Piscina individual	0,06
Piscina coletiva	0,03
Campos de ténis	0,03
Outros equipamentos de lazer	0,04
Qualidade construtiva	Até 0,15
Localização excecional	Até 0,10
Sistema central de climatização	0,03
Elevadores em edifícios de menos de quatro pisos	0,02
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Localização e operacionalidade relativas	Até 0,10

(Redação do Decreto-Lei n.º 41/2016, de 01/08)

Localizaçao e Operacionalidade Relativas includes a long list of parameters

Many distinct qualities are grouped into one rating.

Portaria n.o 982/2004 de 4 de Agosto, Annex II

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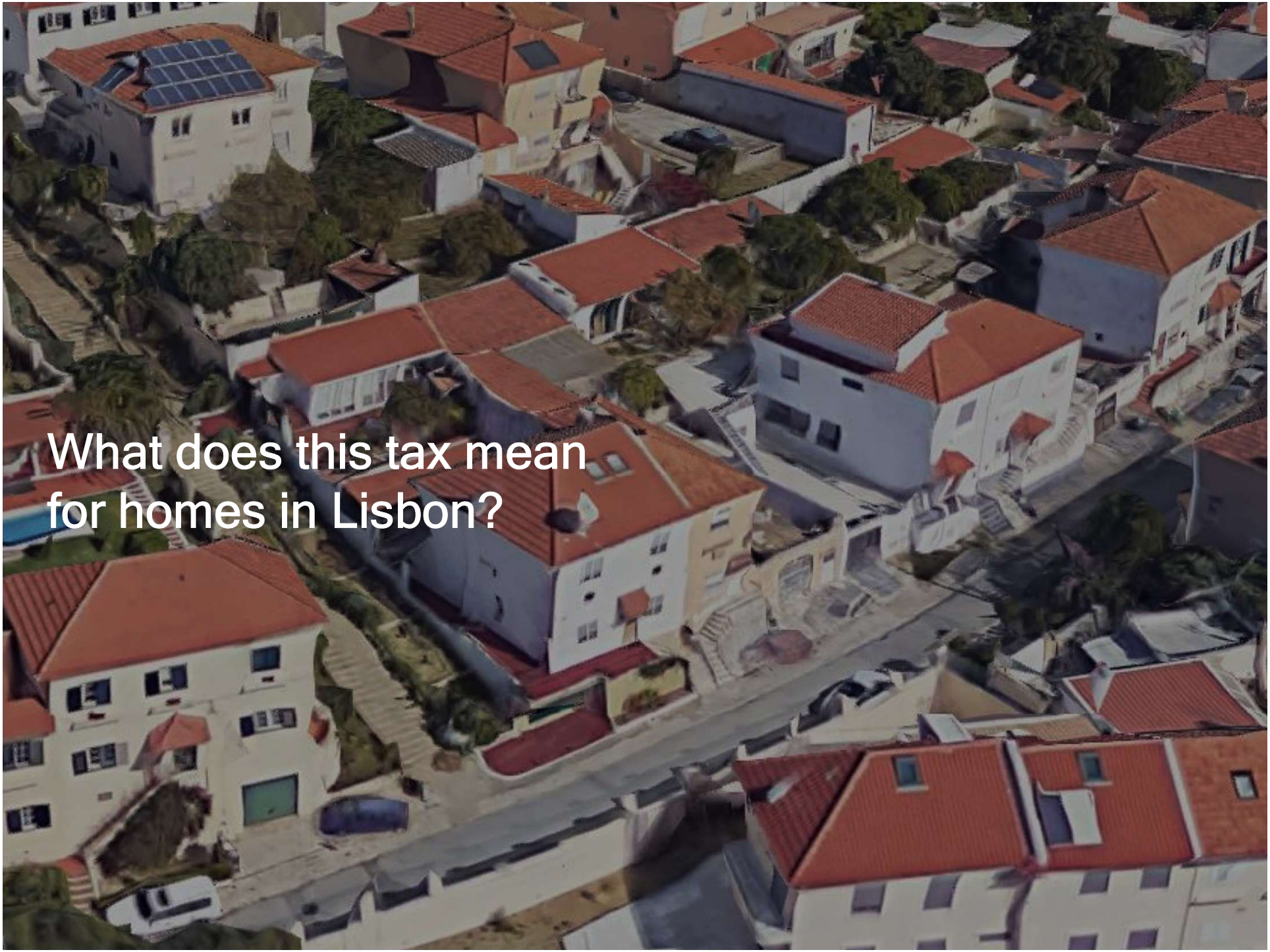
What does this tax mean
for homes in Lisbon?

Current Tax Assessment: Example

REFERENCE FRAME TO STAY WITHIN

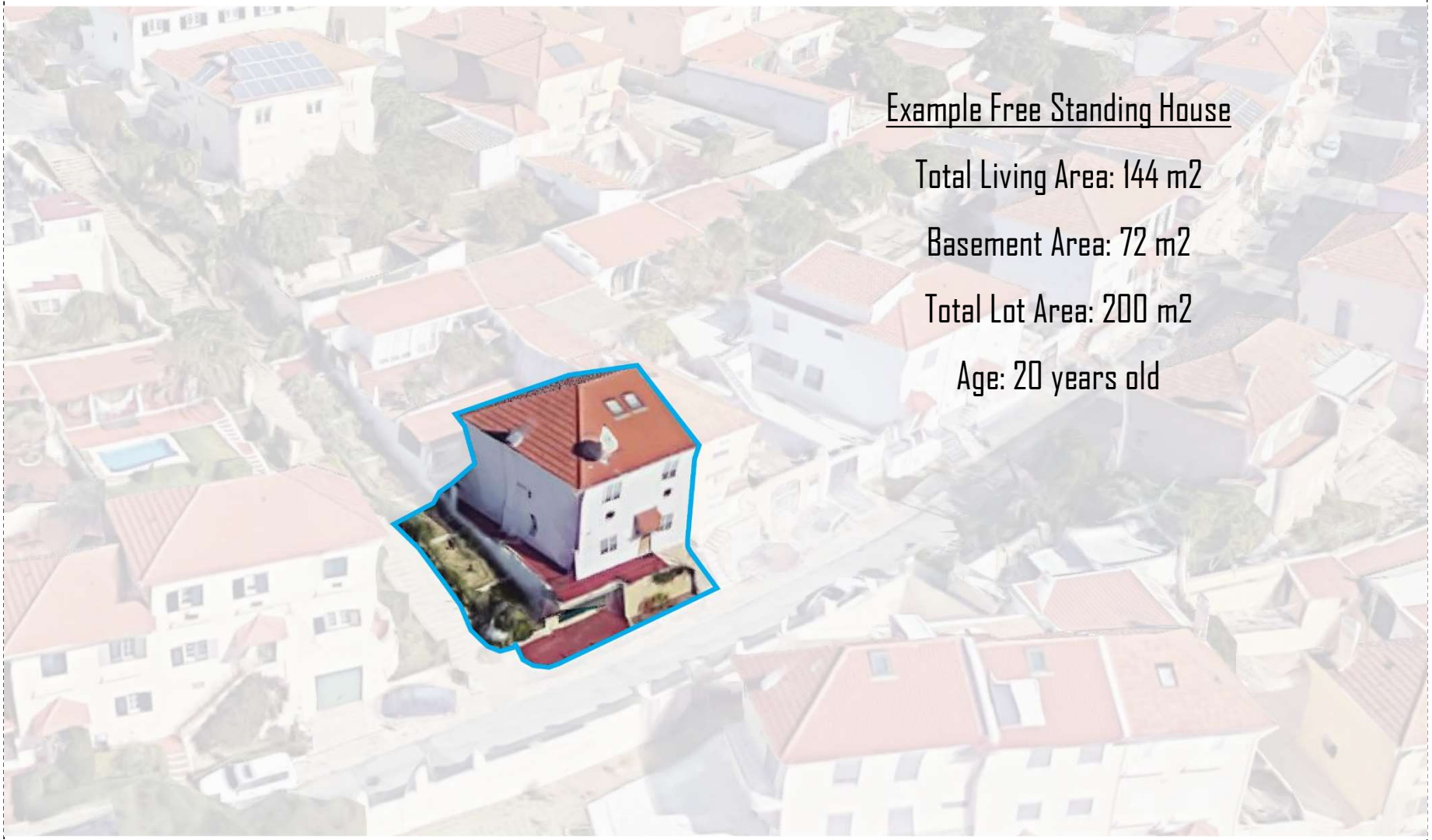

Image: Google Maps Street View

Current Tax Assessment: Example

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IMI Property Tax Value Calculation	Coefficient	Value	Units	Assumptions
base value of built-in property	Vc	603	euros/m2	Average cost of construction: 482.40 euros/m2 + 25% for value of land (via ordinance 345-B/2016)
total area of the building construction plus area in excess of building ground	A	400.07	m2	Assume 20 year old individual house with backyard (200m2 house + 100 m2 open space)
type of building coefficient	Ca	1	-	Housing coefficient = 1.0
location coefficient	Cl	2.4	-	From SIMMI map
quality and comfort coefficient	Cq	0.9-1.2	-	Assuming the upper and lower limits of "localizaçao e operacionalidade relativas" with a range of -10% to +20%, keeping all else equal.
age of building coefficient	Cv	0.85	-	Age coefficient for 16-20 year old house = 0.85
Taxable Net Worth (Cq lower limit)	Vt	€ 442,921		Calculating the Taxable Net Worth: Vt = Vc × A × Ca × Cl × Cq × Cv
Taxable Net Worth (Cq upper limit)		€ 590,561		
Tax Rate (lower limit)	**0.3%**	**€ 1,329**		**Assuming the IMI tax rate for 2017 for Lisbon: 0.3%**
Tax Rate (upper limit)		**€ 1,772**		
Delta in Total Tax	**-**	**€ 443**		

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Current Tax Assessment: Example

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Tax Rate (lower limit)	**0.3%**	**€ 1,329**	**Assuming the IMI tax rate for 2017 for Lisbon: 0.3%**
Tax Rate (upper limit)		**€ 1,772**	
Delta in Total Tax	**-**	**€ 443**	

The assessment is subjective and can vary greatly.

Tools exist to do the assessment in a scientific, methodical, and simple way.

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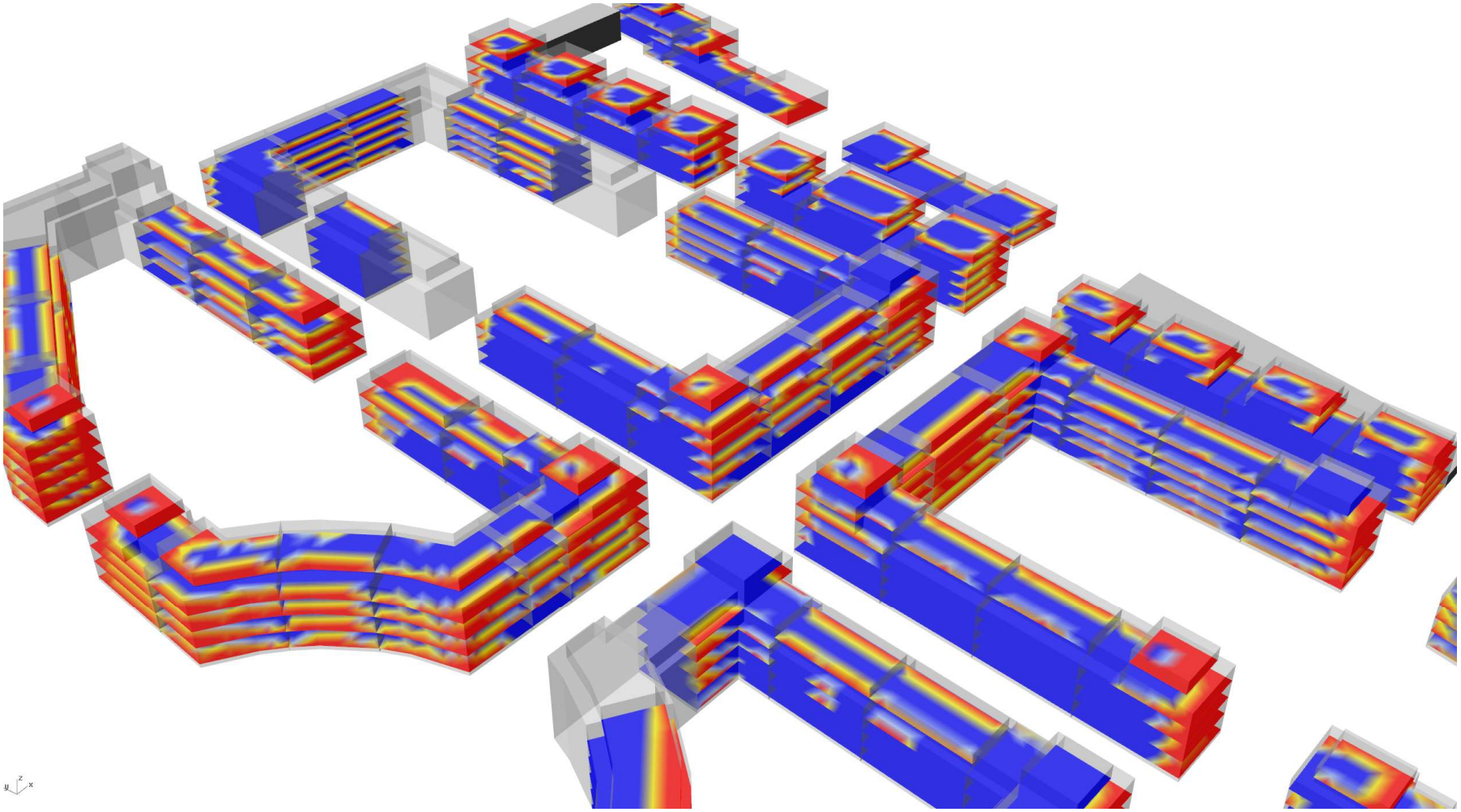
Dynamic Daylight Simulations



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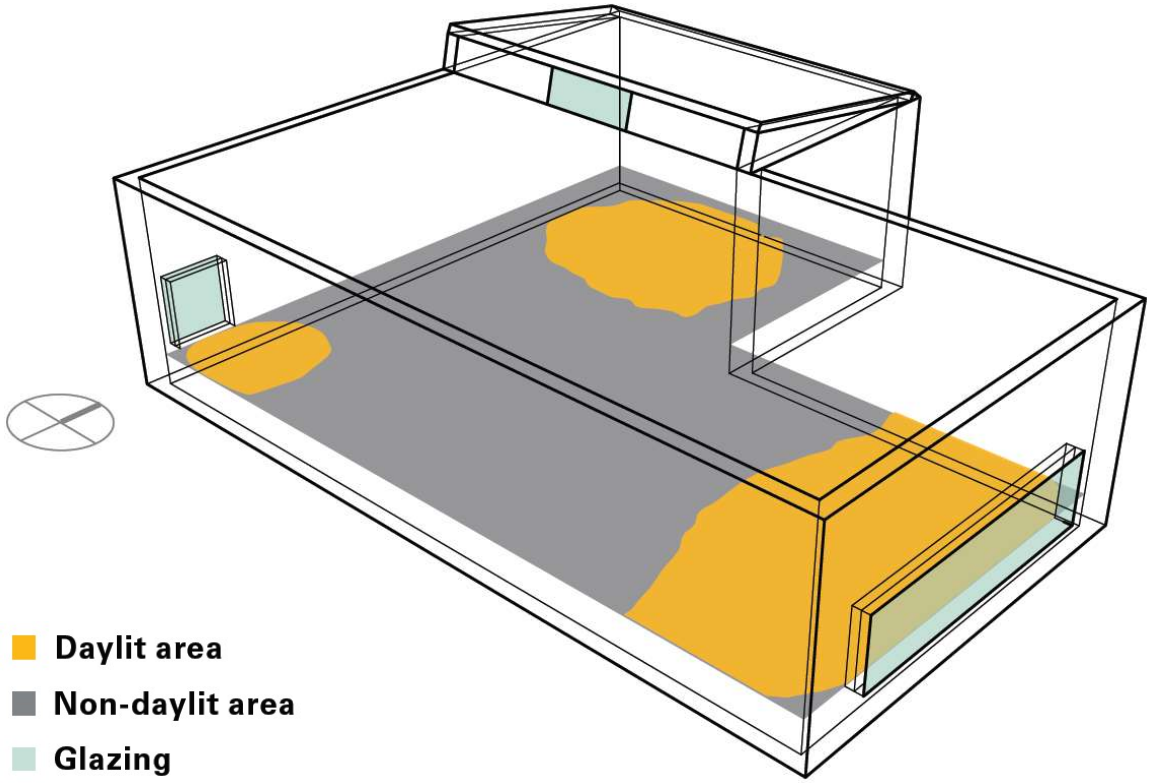
How do we measure daylit area?

REFERENCE FRAME TO STAY WITHIN



Within the daylit area illuminances levels due to natural light should be adequate, useful and balanced for most of the year.

Reinhart (2015) 'Daylighting handbook I: Fundamentals, Designing with the sun'

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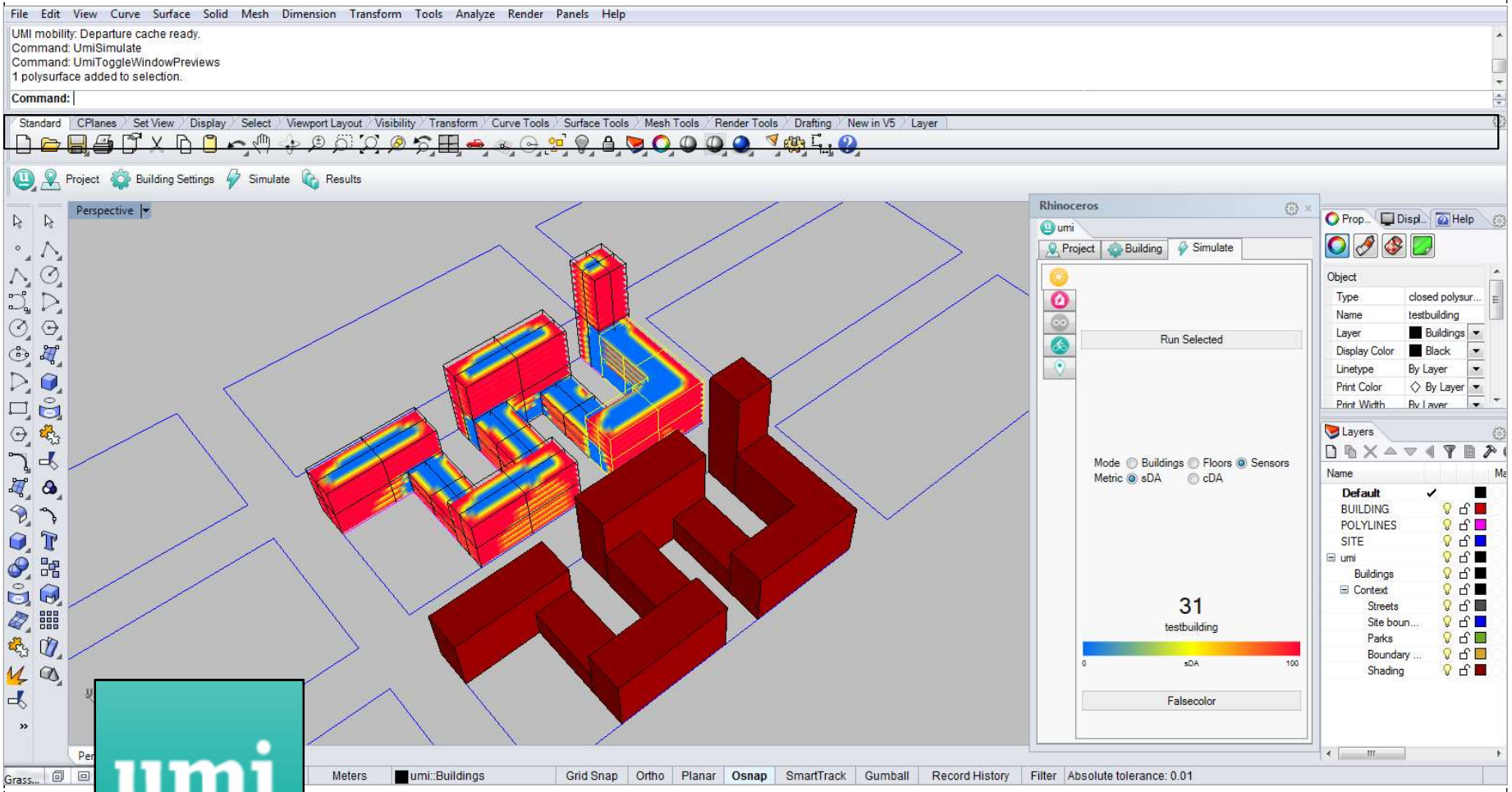
Urban Scale Daylight Simulations

REFERENCE FRAME TO STAY WITHIN



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Case study residential districts

Olivais N / Encarnacao

867 buildings
50% Period 3
35% Period 4
15% Period 5

Cabo Ruivo

139 buildings
92% Period 5
8% Period 6

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Simulation-Based Assessment

REFERENCE FRAME TO STAY WITHIN

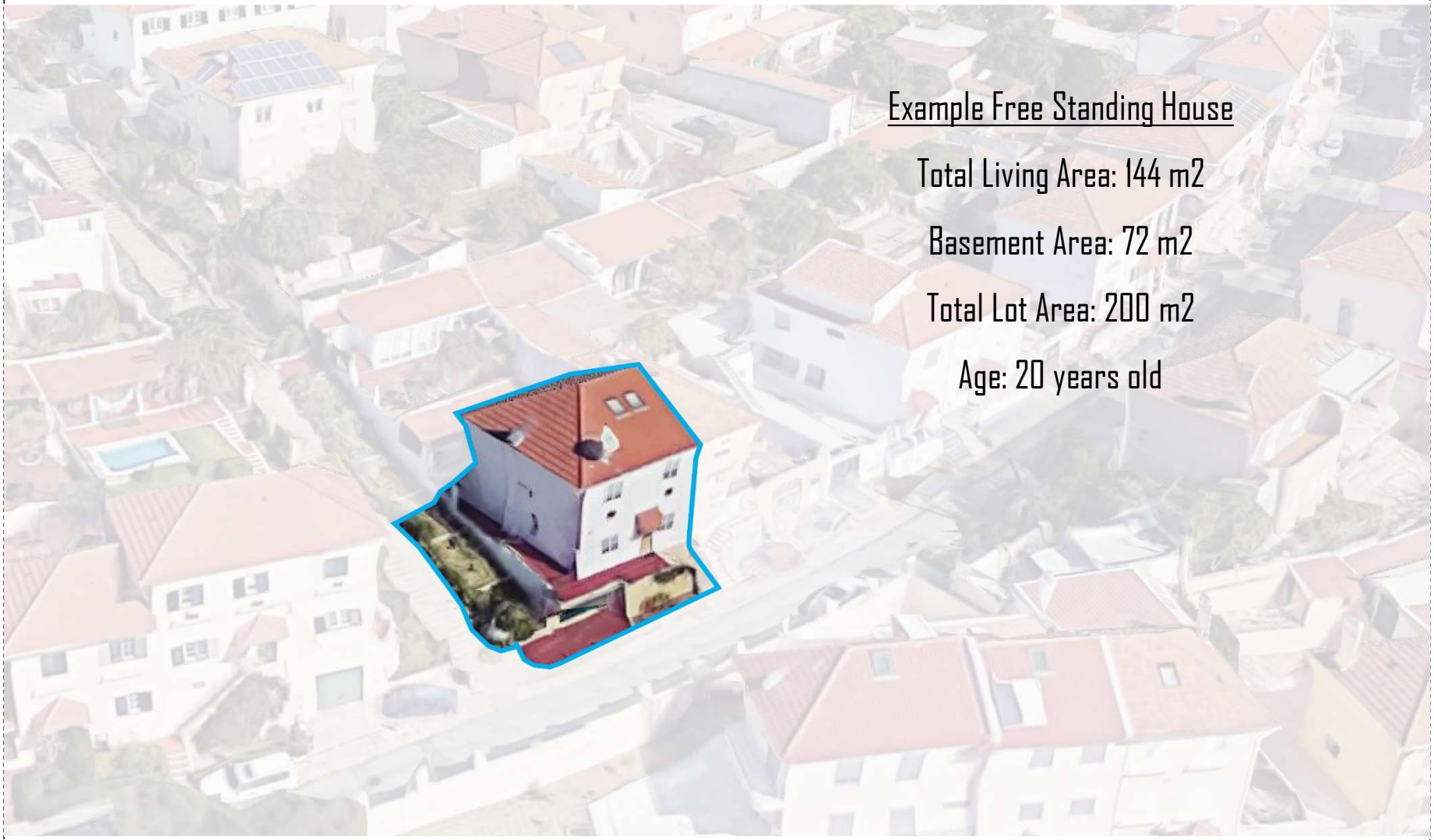

Image: Google Maps Street View

Simulation-Based Assessment

REFERENCE FRAME TO STAY WITHIN

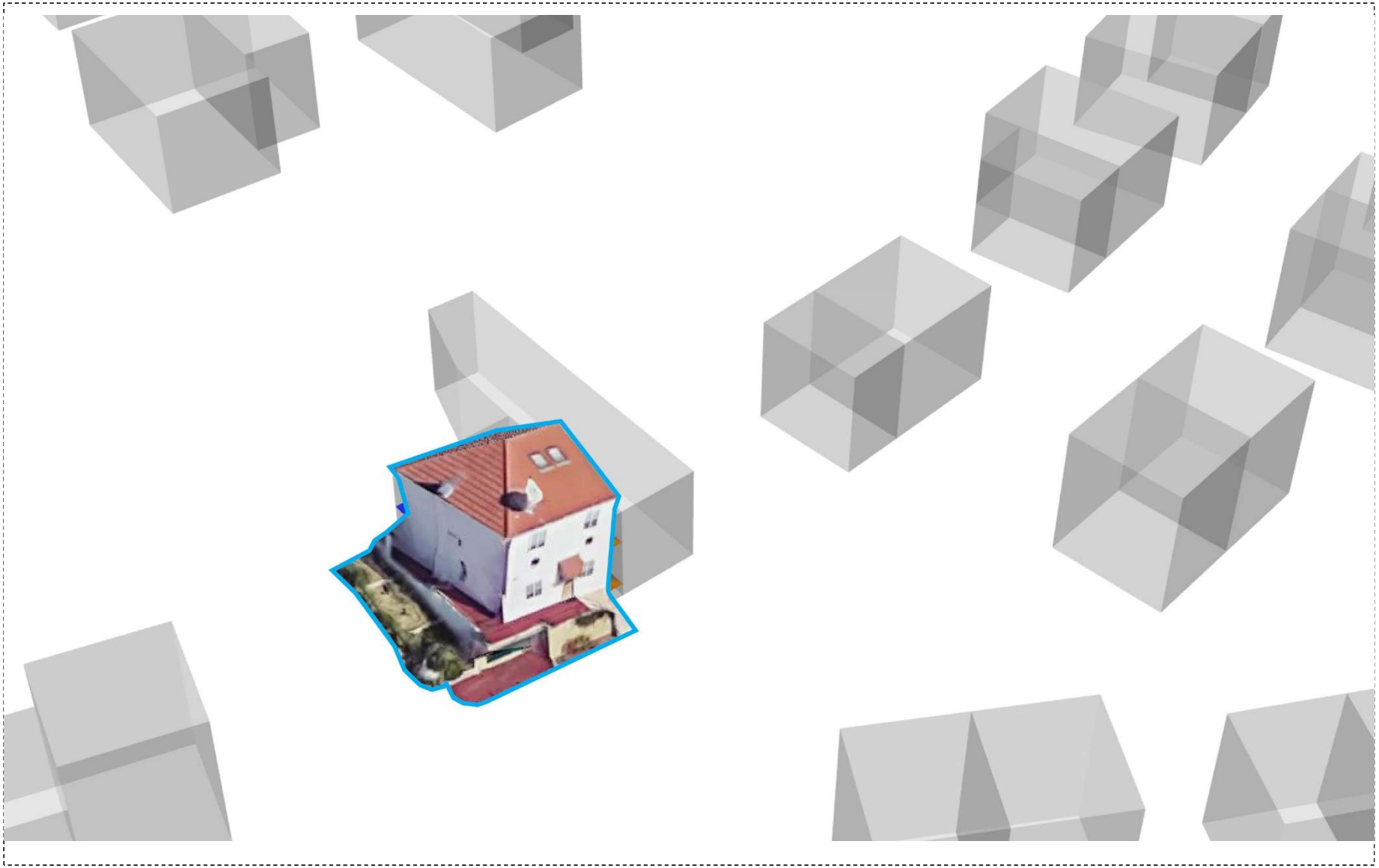

Image: Google Maps Street View

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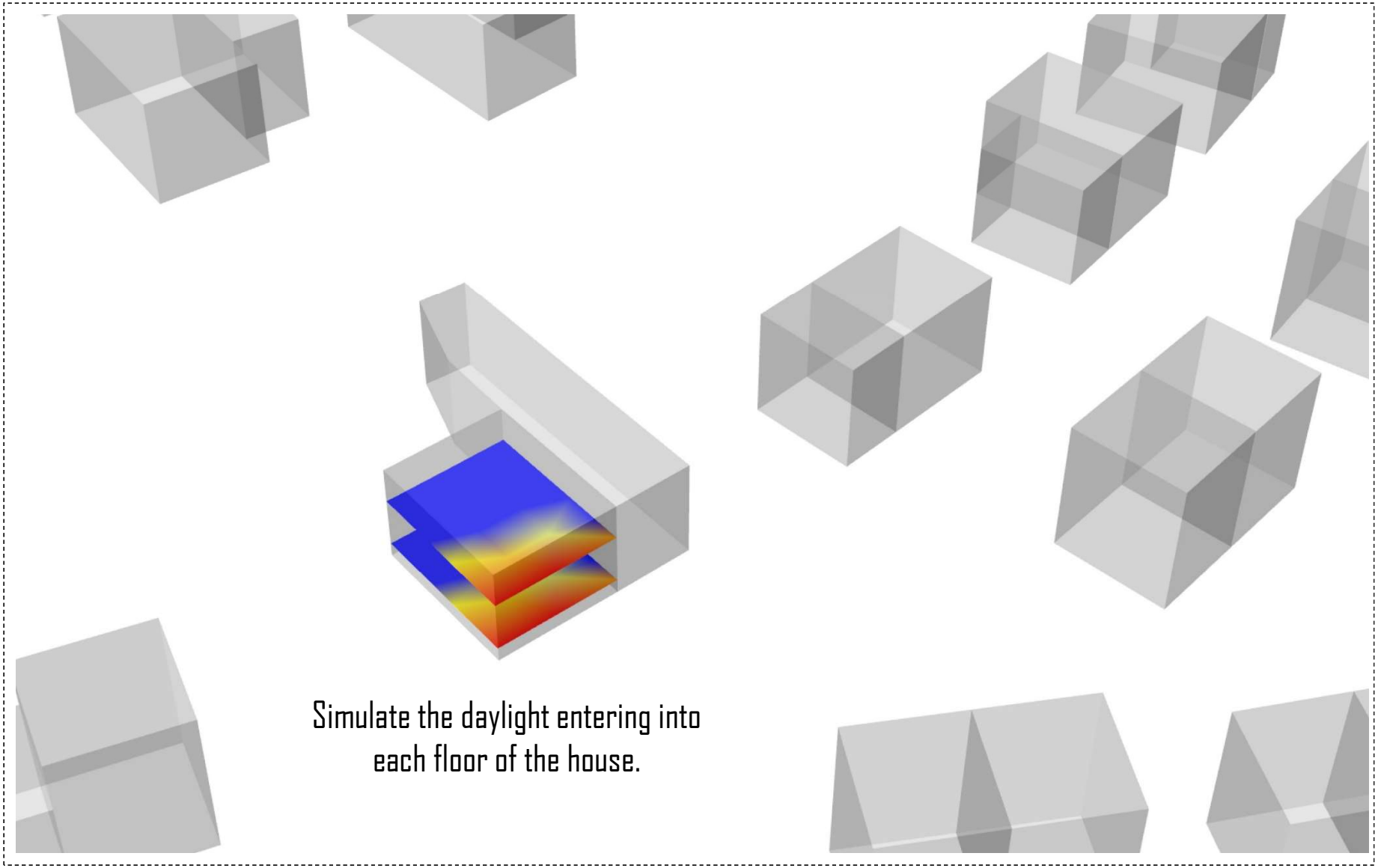
Simulation-Based Assessment

REFERENCE FRAME TO STAY WITHIN



Simulate the daylight entering into each floor of the house.

Image: Google Maps Street View

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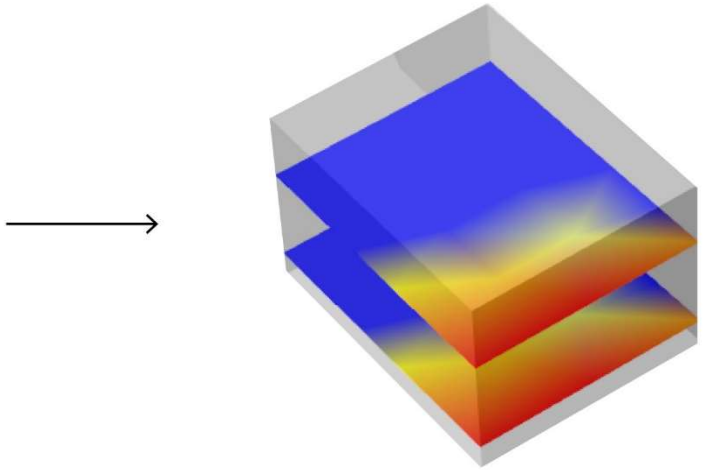
Simulation-Based Assessment

REFERENCE FRAME TO STAY WITHIN

Current assessment based on

south facing windows, views, others?...



Simulation result* on 0-100 scale:

23% sDA

*(300 lux, for all sunlit hours)

Image: Google Maps Street View

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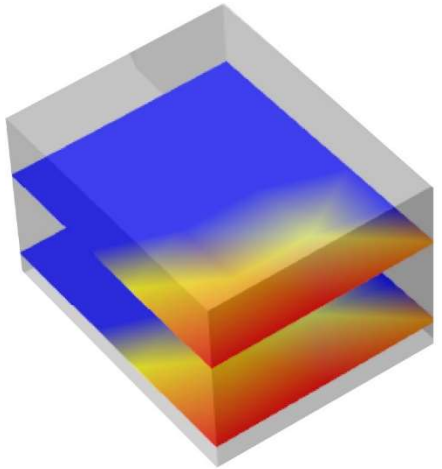
Simulation-Based Assessment

REFERENCE FRAME TO STAY WITHIN

Building simulation tools provide
quantitative metrics
on which the tax code can be based.



Localizaçao e operacionalidade relativas:

-10% ← Cq → +20%

Daylight Metric:

0% ← sDA → 100%

Image: Google Maps Street View

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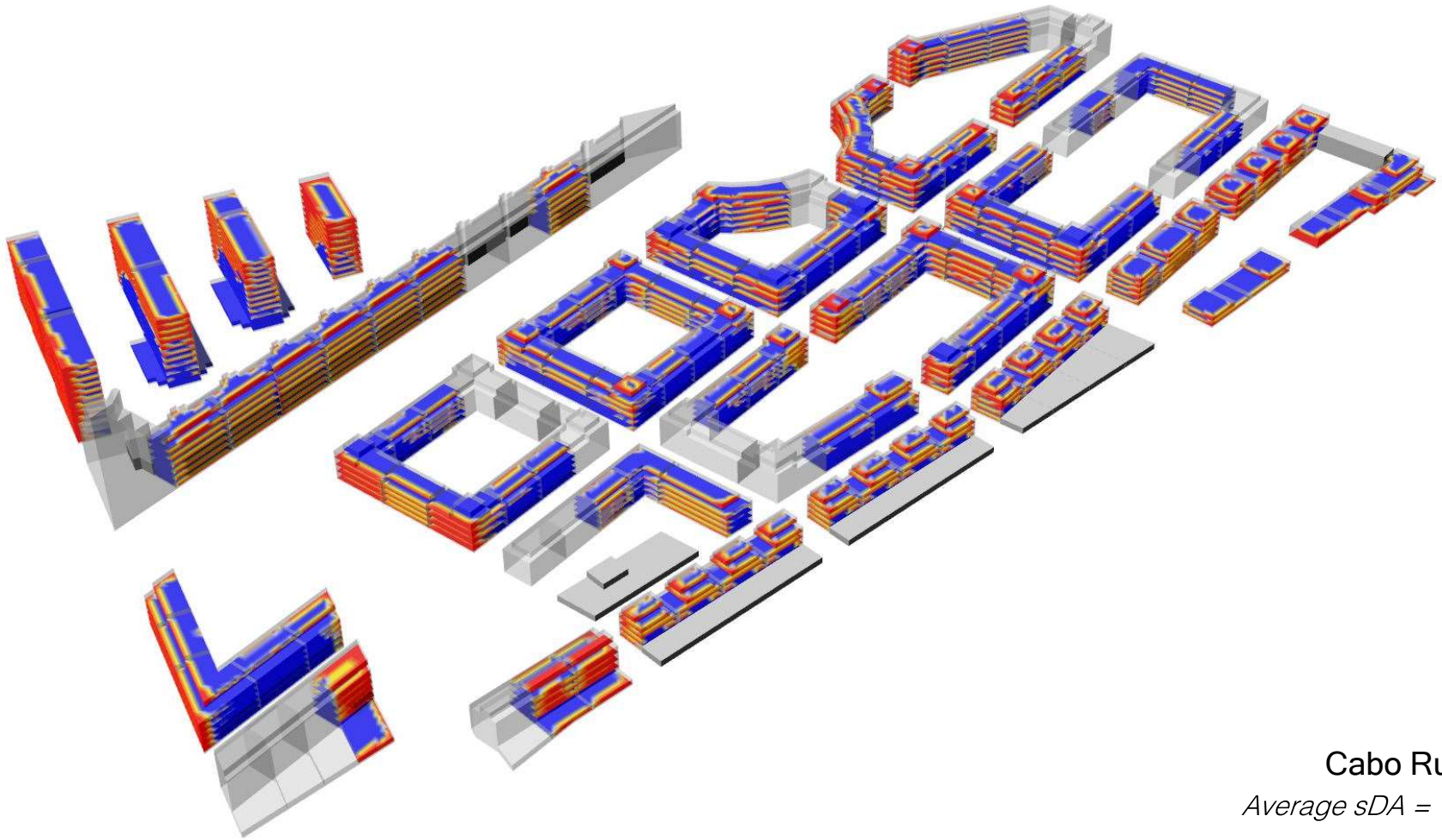
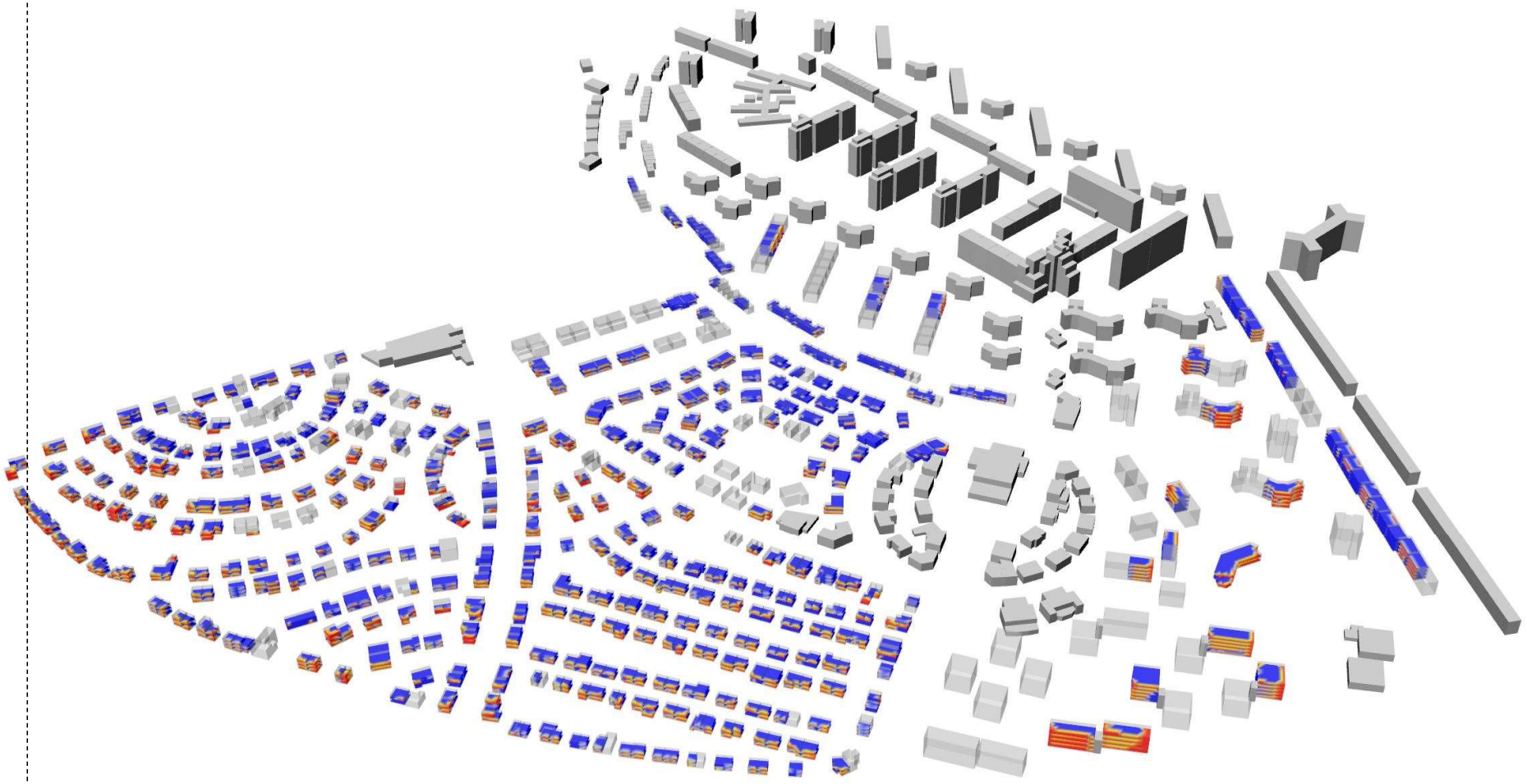
Results: Cabo Ruivo

REFERENCE FRAME TO STAY WITHIN



Results: Olivais / Encarnacao

REFERENCE FRAME TO STAY WITHIN



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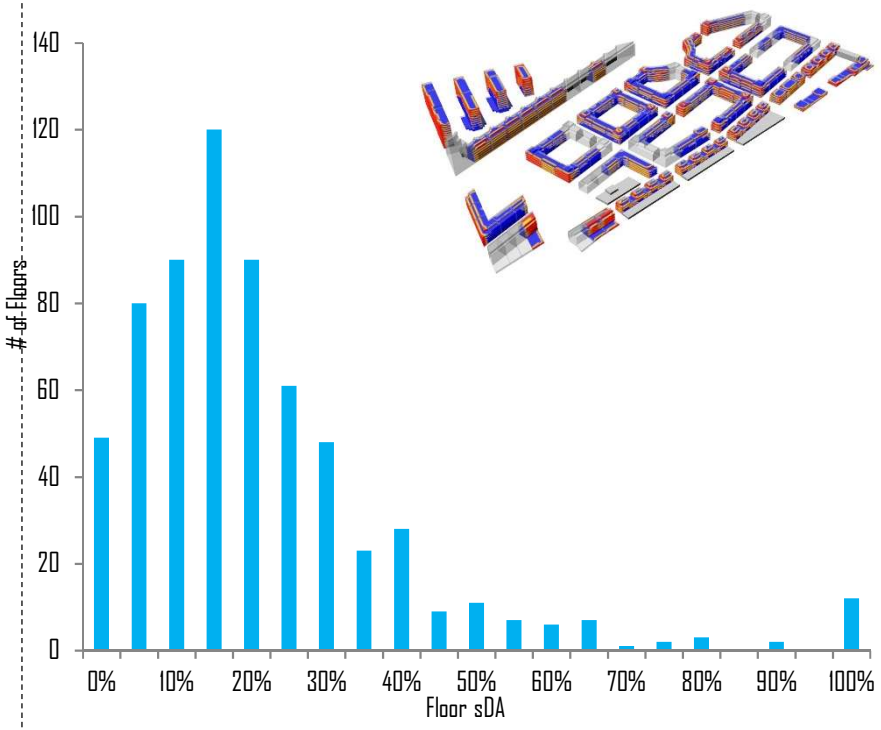
Site-Wide Distribution of sDA Results

REFERENCE FRAME TO STAY WITHIN

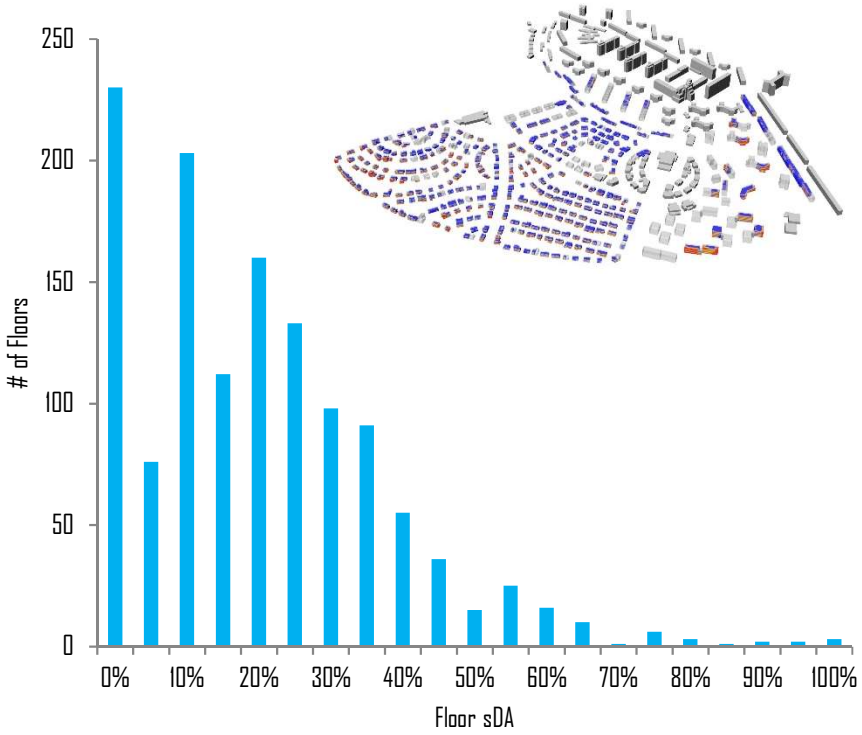
Cabo Ruivo



Average sDA: 19%

WWR: 26-31%

Olivais / Encarnacao



Average sDA: 18%

WWR: 13-20%

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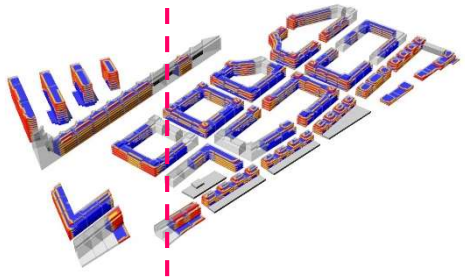
Site-Wide Distribution of sDA Results

REFERENCE FRAME TO STAY WITHIN

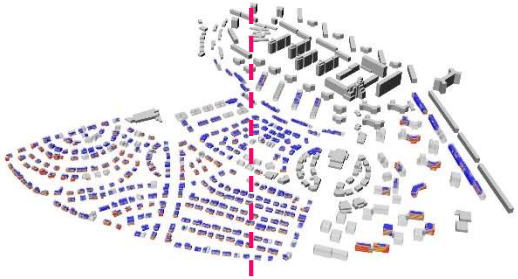
Cabo Ruivo

Average sDA = 19%



Olivais / Encarnacao

Average sDA = 18%



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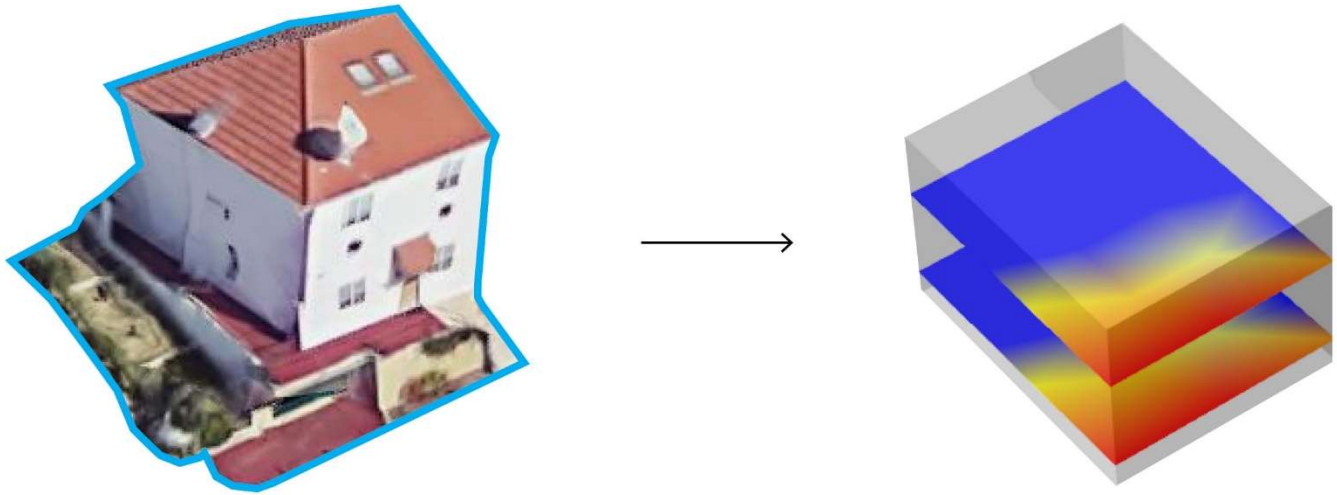
Some key ideas...

REFERENCE FRAME TO STAY WITHIN



- *It is critical to value indoor environmental quality through public regulation to ensure that homes are built to a high standard.*
- *The tools exist to measure daylight in homes at the urban scale.*
- *The use of these tools can inform the progressive taxation scheme to enable more objective and fair assessment.*

Image: Google Maps Street View

Productive urban landscapes

Khadija Benis / MIT

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The challenge of feeding our growing cities

United Nations, Department of Economic and Social Affairs, Population Division (2014) 'World Urbanization Prospects: The 2014 Revision, Highlights.

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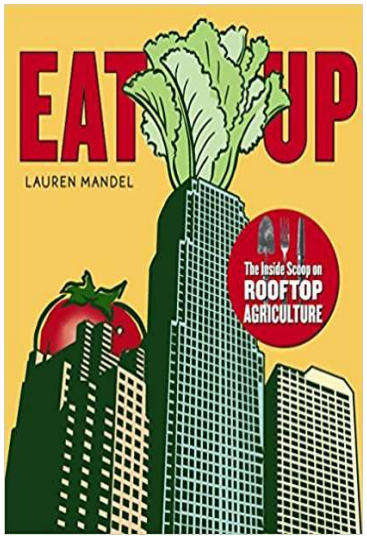
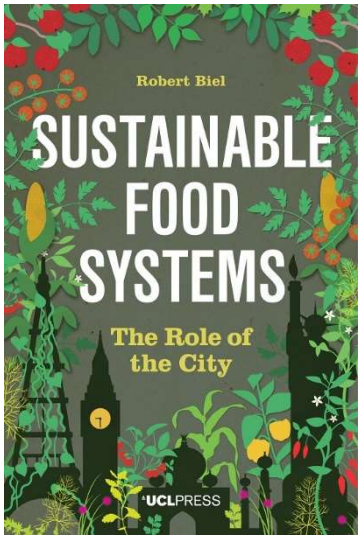
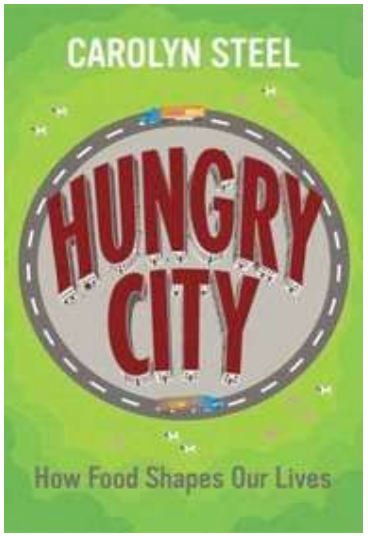
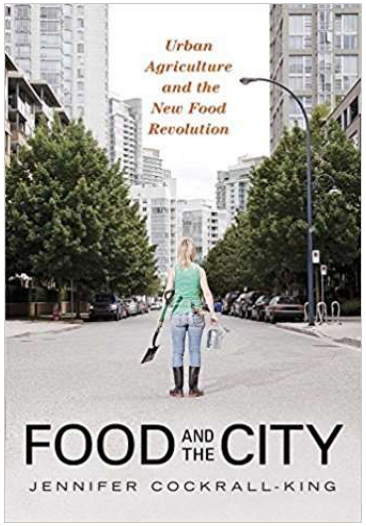
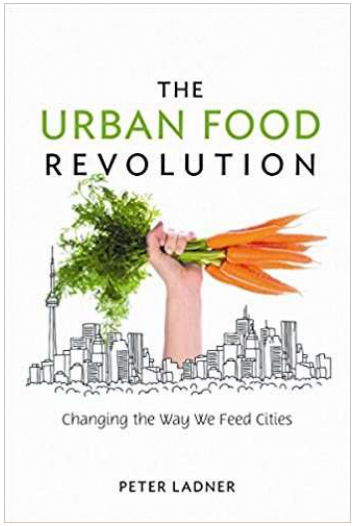
The challenge of feeding our growing cities

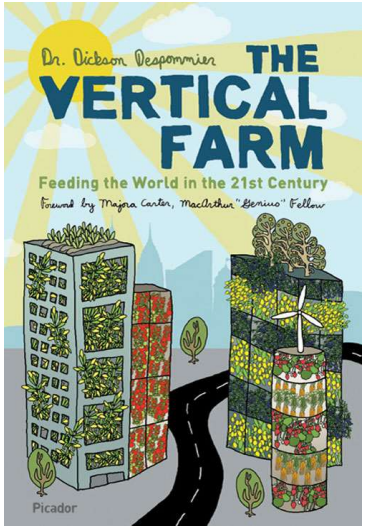












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The challenge of feeding our growing cities

Signatory cities

The 163 Cities Of The Milan Urban Food Policy Pact

- Abidjan
- Alcala de Henares
- Algiers
- Almere
- Amsterdam
- Ancona
- Antananarivo
- Arusha
- Astana
- Athens
- Austin
- Baltimore
- Banjul
- Barcelona
- Bari
- Basel
- Beijing
- Belo Horizonte
- Berlin
- Bethlehem
- Bilbao
- Birmingham
- Bobo-Dioulasso
- Bogota
- Bologna
- Bordeaux
- Brazzaville
- Bruges
- Brussels
- Bucharest
- Buenos Aires
- Cagliari
- Cape Town
- Catania
- Chanchamayo
- Chicag
- Cho ging
- ogr
- lombo
- Copenhagen
- Cordoba (Argentina)
- Cordoba (Spain)
- Cremona
- Curitiba
- Daegu
- Dakar
- Dénia
- Douala
- Dubai
- Ede
- Florence
- Foggia
- Frankfurt
- Fuenlabrada
- Funchal
- Geneva
- Genoa
- Ghent
- Godella
- Granollers
- Grenoble
- Guangzhou
- Guarulhos
- Guatemala City
- Haapsalu
- Hebron
- Johannesburg
- Kitwe
- Kyoto
- La Paz
- Las Juntas
- Las Palmas de Gran Canaria
- Liège
- Ljubljana
- London
- Luanda
- Lugano
- Lusaka
- Lyon
- Madison
- Madrid
- Malaga
- Maputo
- Mar Del Plata
- Marseille
- Medellin
- Melbourne
- Mendoza
- Menorca
- Mérida
- Mexico City
- Miami
- Mieres
- Milan
- Modena
- Molfetta
- Montpellier
- Montreal
- Moscow
- Nairobi
- Nantes
- Navas
- N'Djamena
- New Delhi (East and South MC)
- New York
- Niamey
- Nouakchott
- Osaka
- Oss
- Oviedo
- Palermo
- Pamplona/Iruña
- Paris
- Parma
- Pemba
- Pittsburgh
- Porto Alegre
- Praia
- Qardho
- Quelimane
- Quito
- Rennes
- Riga
- Rio de Janeiro
- Rivas Vaciamadrid
- Rome
- Rotterdam
- Sacile
- San Fernando del Valle de Catamarca
- San Francisco
- San Sebastian/Donostia
- Sao Paulo
- Seoul
- Shanghai
- s-Hertogenbosch
- Sucre
- Tegucigalpa
- Tel Aviv
- The Hague
- Thessaloniki
- Tirana
- Toronto
- Toyama
- Tunis
- Turin
- Udine
- Utrecht
- Valencia
- Vancouver
- Venice
- Vienna
- Villanueva de la Cañada
- Vitoria-Gasteiz
- Wanju
- Warsaw
- Washington DC
- West Sacramento
- Windhoek
- Yaoundé
- Yeosu
- Zagreb
- Zaragoza
- Zurich

LISBON?

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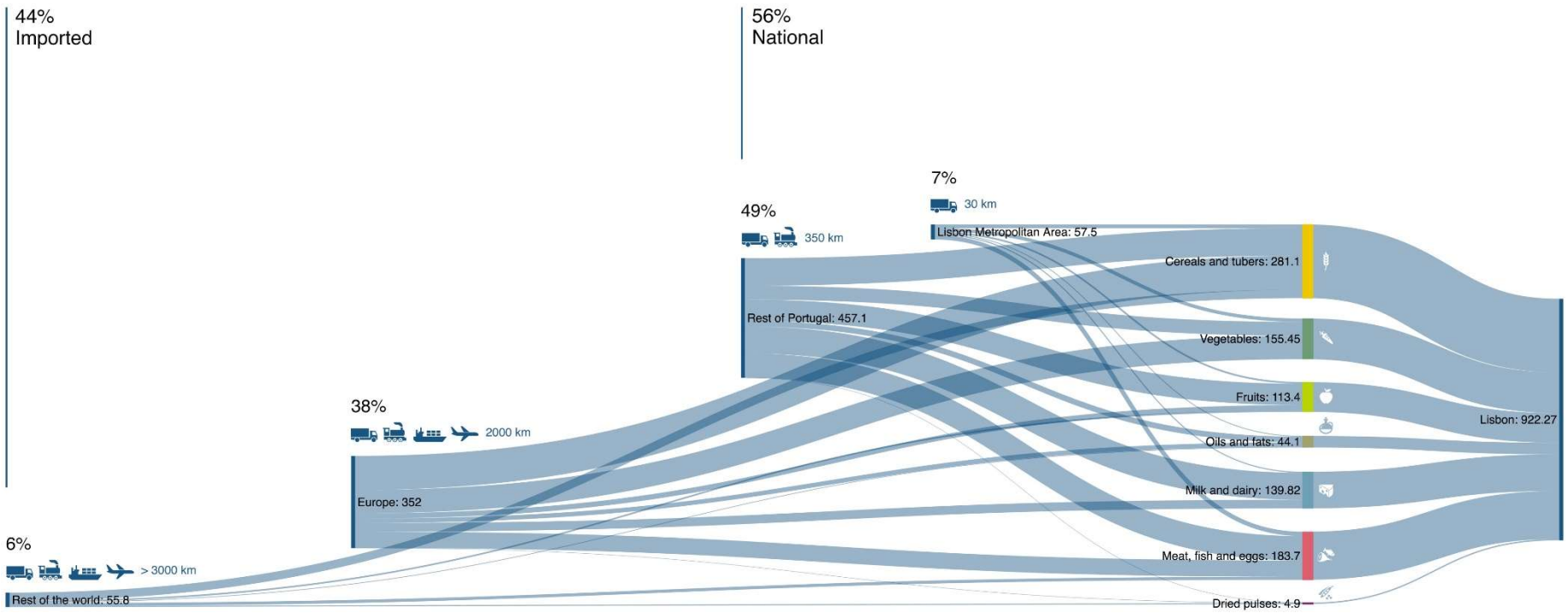
Origin of food consumed in Lisbon in 2013 [kg/cap/y]



Paper. Benis, Ferrão (2017) 'Potential mitigation of the environmental impacts of food systems through urban and periurban agriculture (UPA) – a life cycle approach', Journal of Cleaner Production 140, 784-795

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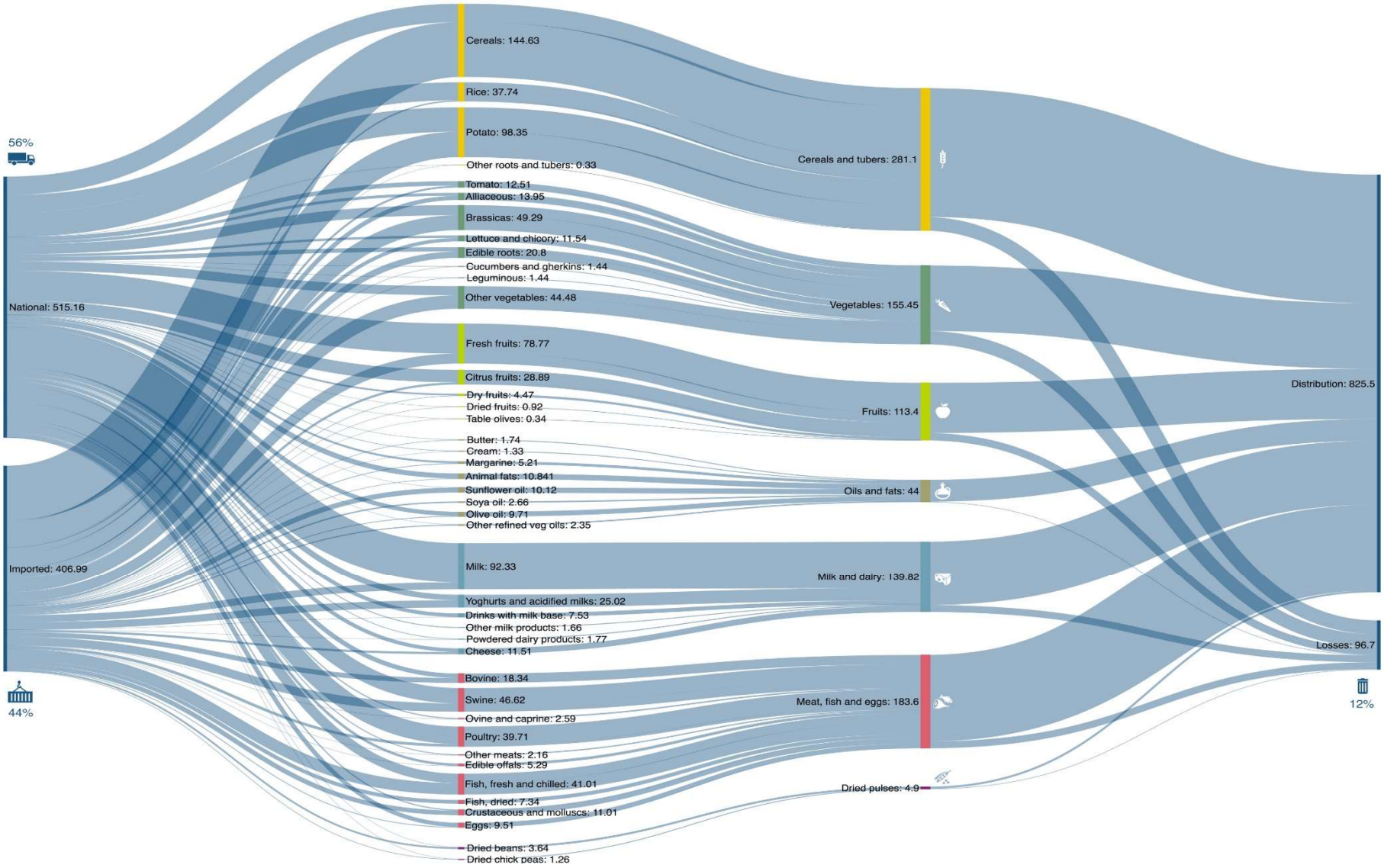
Lisbon food flows in 2013 [kg/cap/y]



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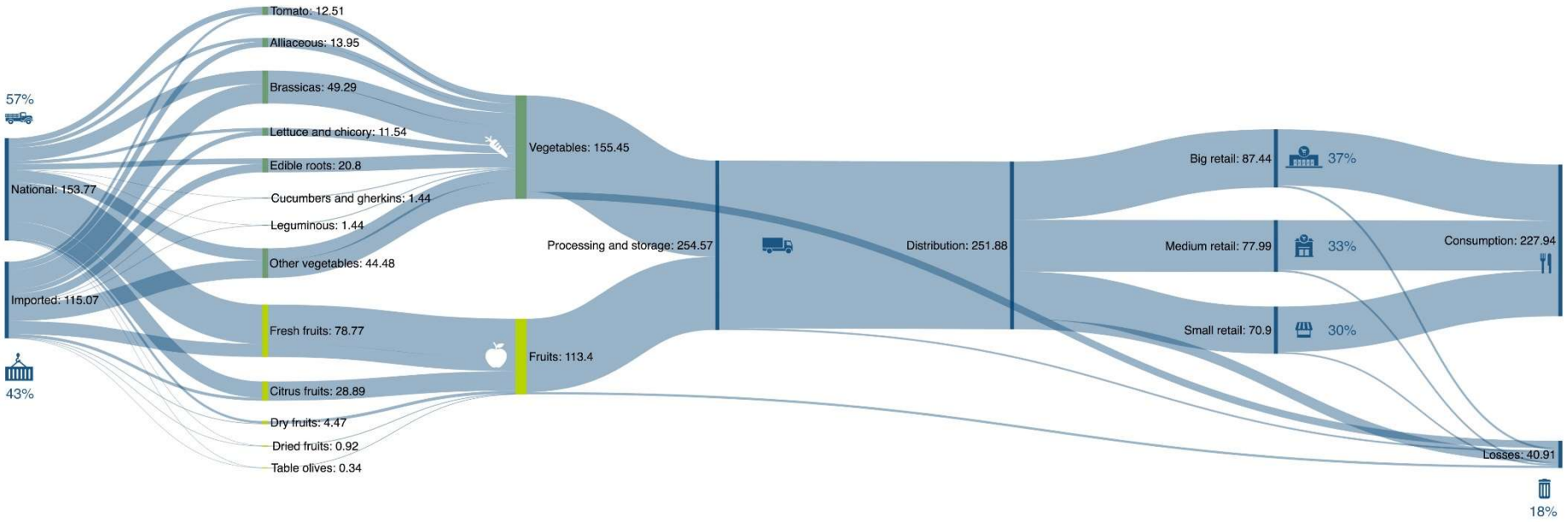
The journey of ‘fresh’ produce



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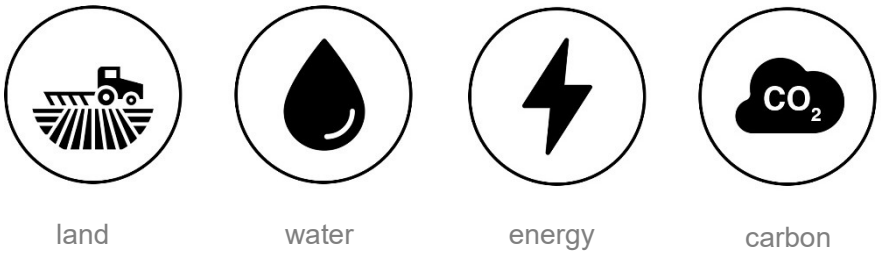
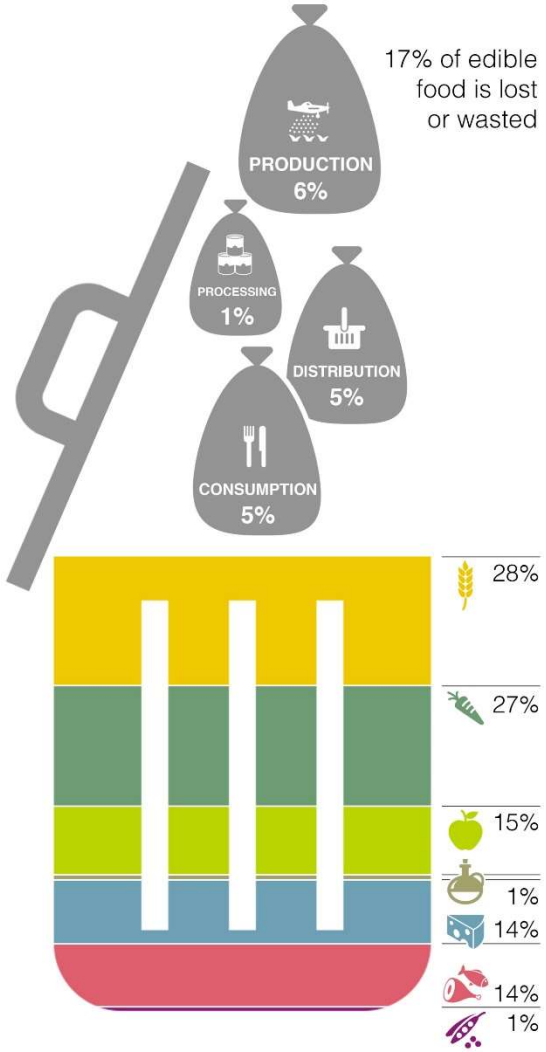
A wasteful food system





Paper. Benis, Ferrão (2017) 'Potential mitigation of the environmental impacts of food systems through urban and periurban agriculture (UPA) – a life cycle approach', Journal of Cleaner Production 140, 784-795

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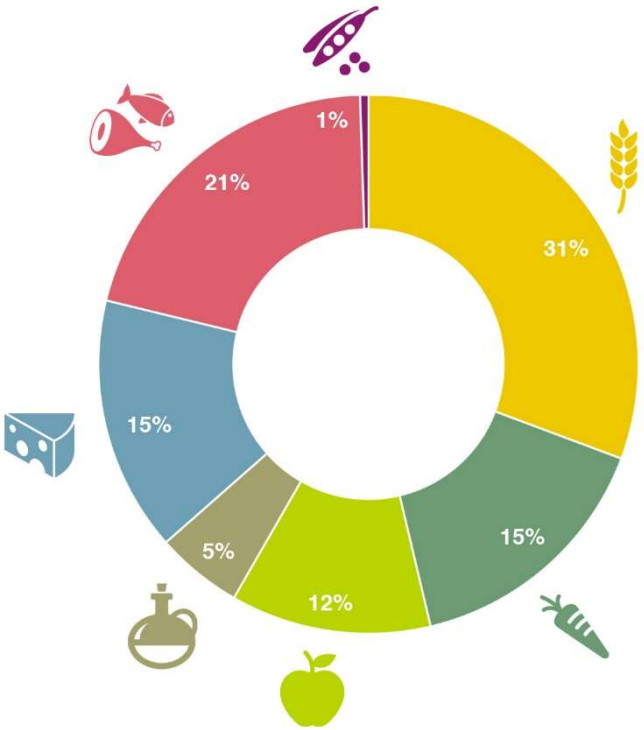
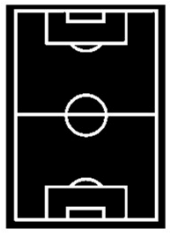
LCA of Current Average Consumption [CAC]



3.45
tCO_2eq

GWP

LU



* Average household size = 2.5 ppl (PORDATA, 2017)

Paper. Benis, Ferrão (2017) 'Potential mitigation of the environmental impacts of food systems through urban and periurban agriculture (UPA) – a life cycle approach', Journal of Cleaner Production 140, 784-795

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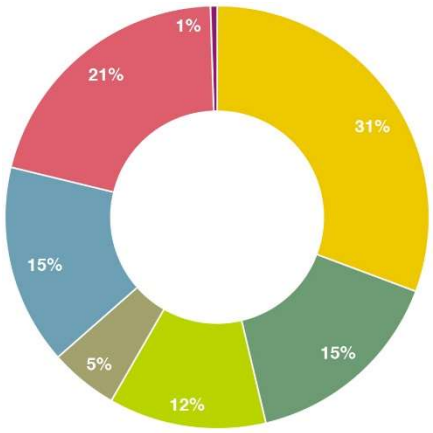
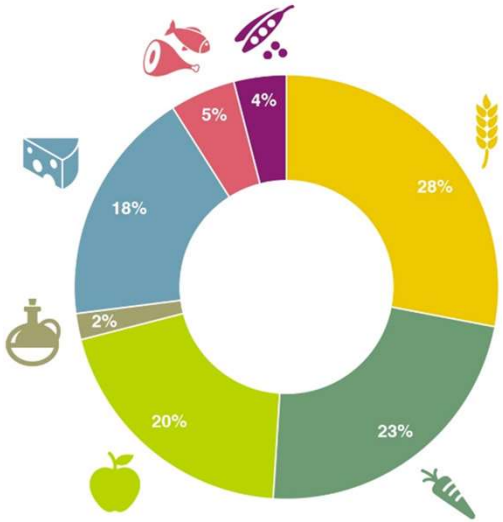
Alternative scenarios

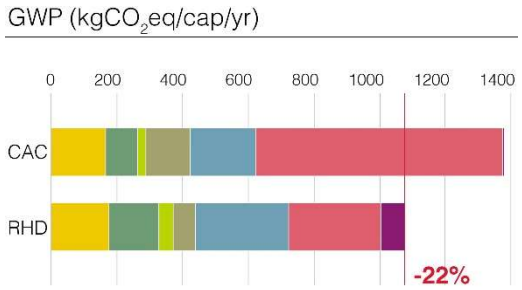


Current Average Consumption



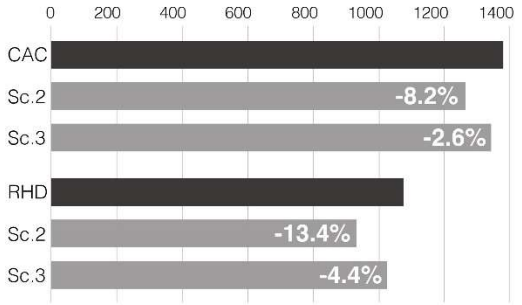
Recommended Healthy Diet

Sc. 1. Recommended Healthy Diet (RHD)



Sc. 2. Eliminating losses and wastage

Sc. 3. Cutting food miles



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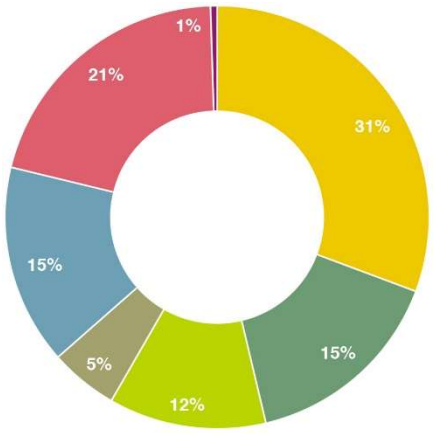
Alternative scenarios



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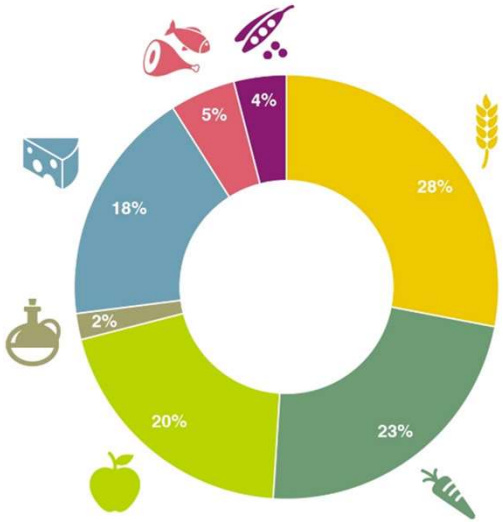

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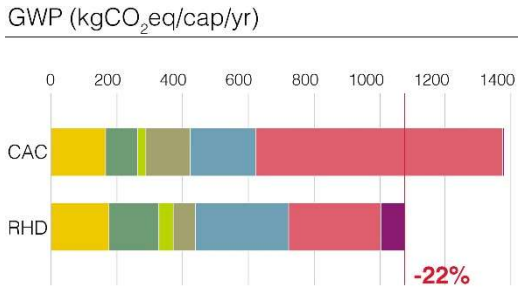

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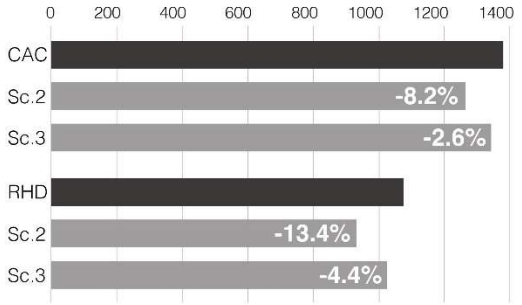

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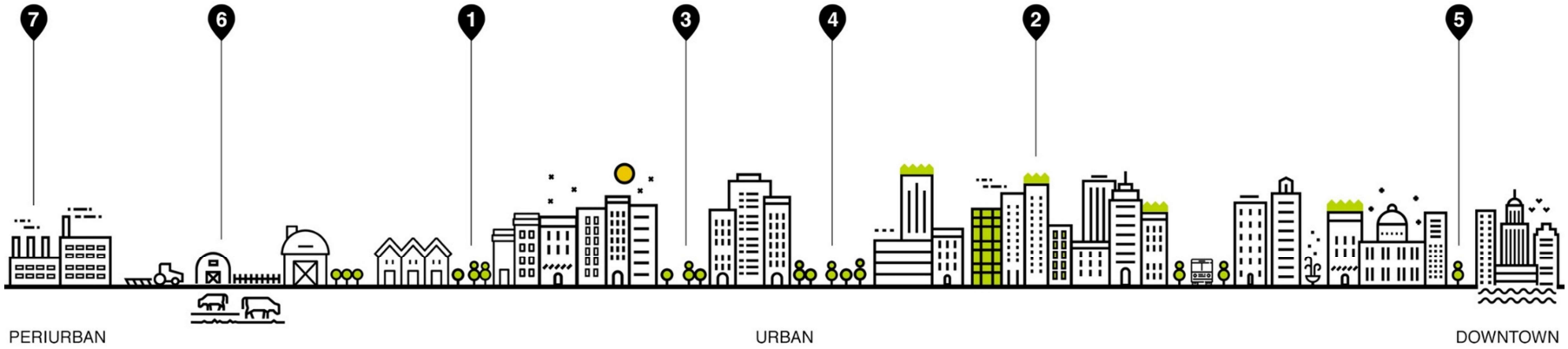
Urban and Periurban Agriculture [UPA]



1	Allotment garden	garden subdivided into leased parcels for individual non-commercial food production, the parcel size usually suiting the needs of a family
2	Building-Integrated Agriculture	(BIA) *coined by T. Caplow in 2007*, high-yield commercial-scale soilless farming within the urban built environment, i.e., on rooftops, facades or indoors
3	Community garden	non-commercial piece of land gardened collectively by a group of people, often used in urban neighborhoods to alleviate the *food desert* effect
4	Edible park	or *foodscape*, use of food plants as design features in a landscape, where plants are used both for aesthetic value and consumption
5	GROW street	*Gardening in the Right-Of-Way* street, with vegetable garden set on the strip between the sidewalk and the street
6	Hamlet	periurban cluster development involving a group of houses and processing facilities arranged around agricultural production or distribution
7	Waste-to-energy plant	waste management facility that combusts wastes to produce electricity

Building-Integrated Agriculture [BIA]

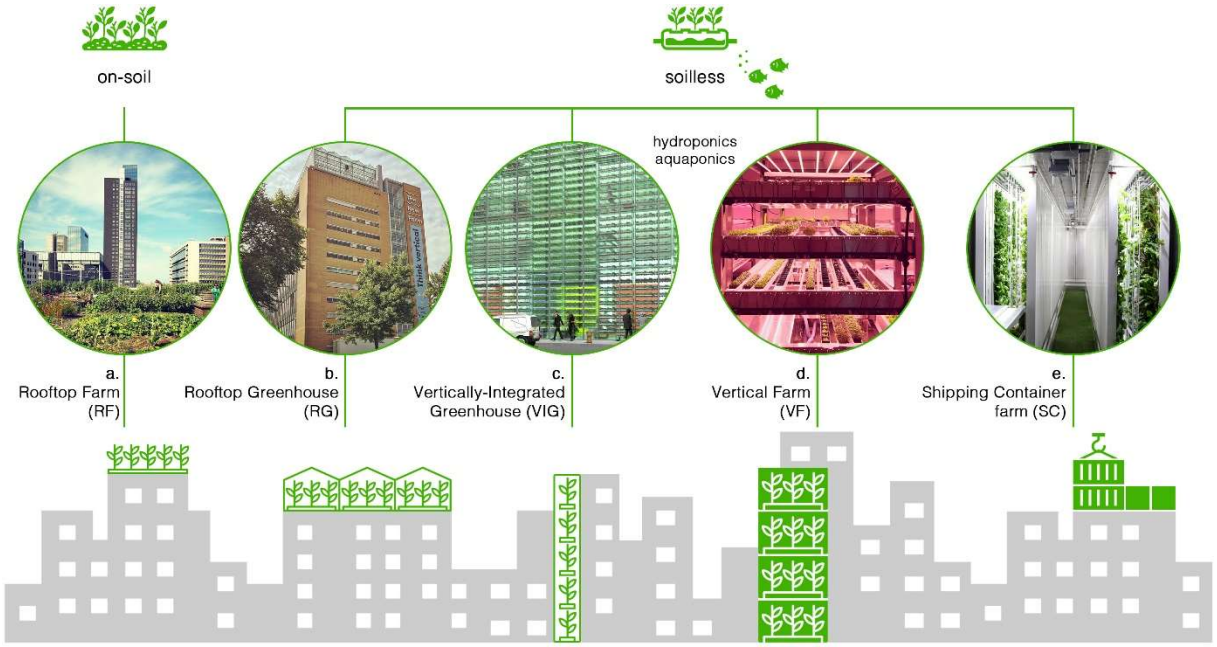
Soilless culture

High yields

90% less water

No land use

Year-round production



Paper. Benis, Ferrão (n.d.) 'Commercial-scale farming in and on buildings – Taking stock of an evolving field in northern countries', Global Food Security, *Manuscript under review*

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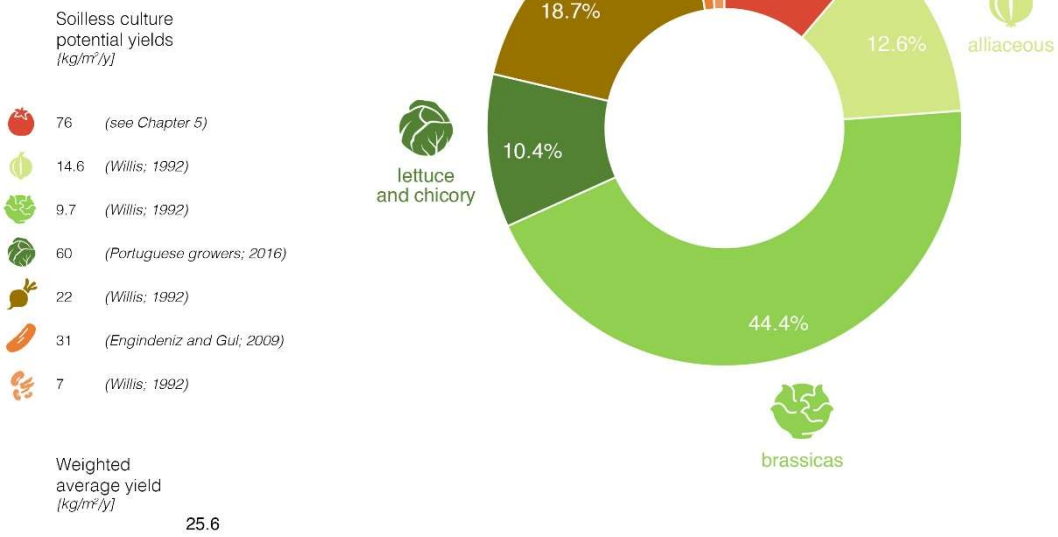
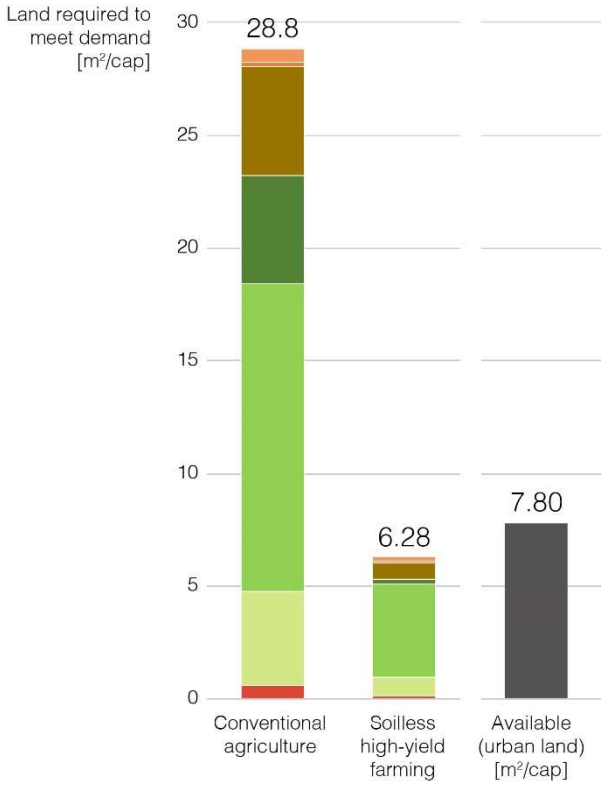
Potential of BIA to feed the Lisbon Metropolitan Area

The LMA can locally meet up to 124% of its demand for the seven main categories of vegetables.





Demand for vegetables vs. required area to meet it

Paper. Benis, Reinhart, Ferrão (2017) 'Development of a simulation-based decision support workflow for the implementation of Building-Integrated Agriculture (BIA) in urban contexts', Journal of Cleaner Production 589-602

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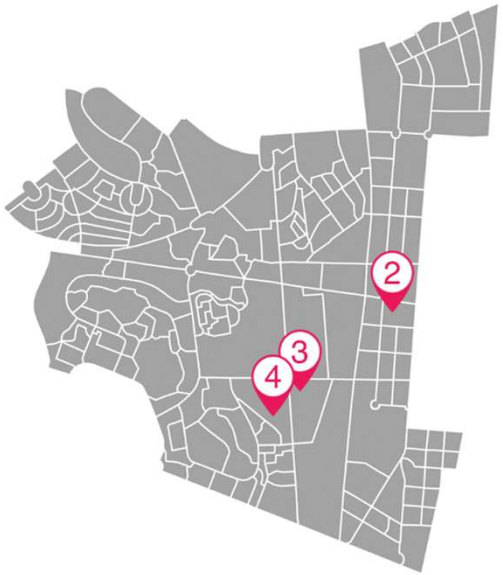
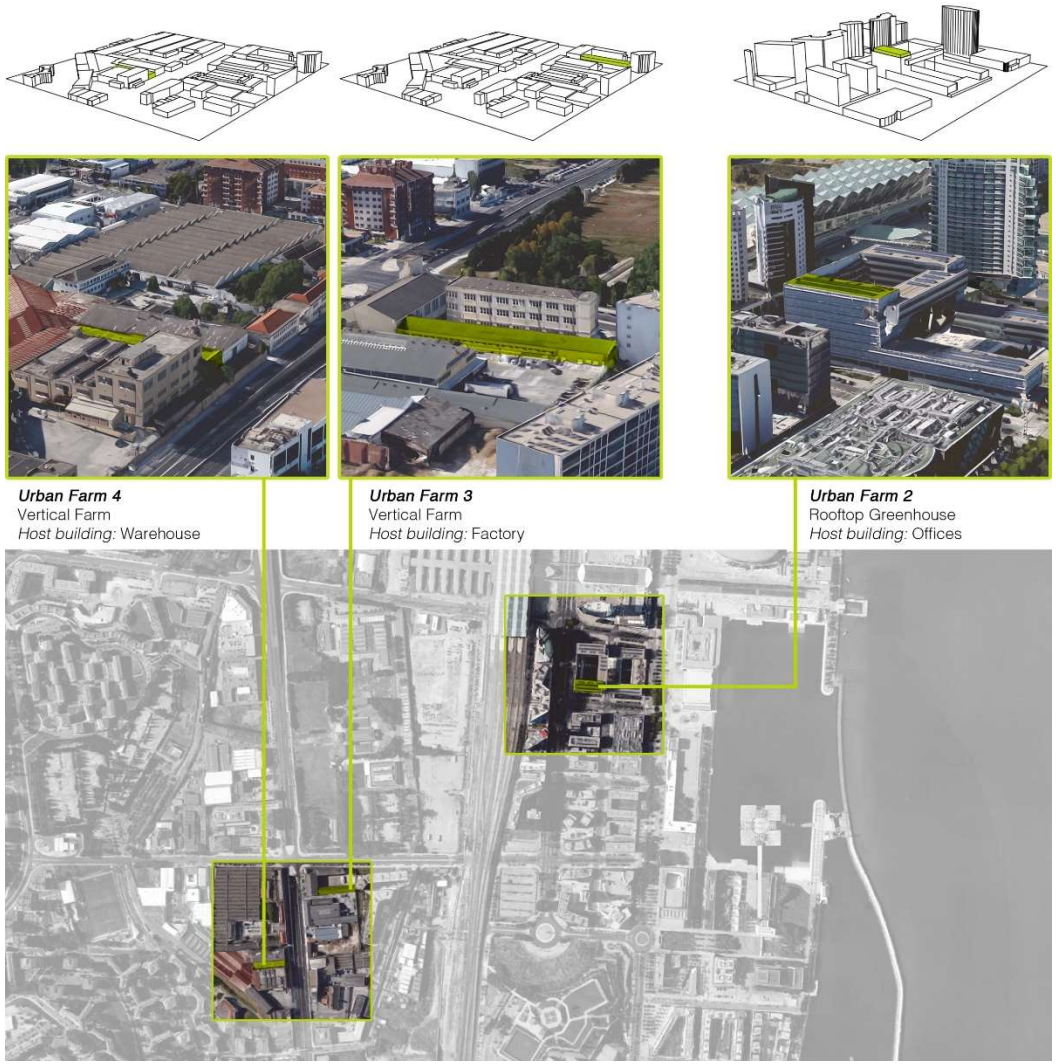
BIA in Parque das Nações [Simulated scenarios]

Three building-integrated farms…
SusCity project area

Average farming area 1,000 m^2
Crop Tomato





Paper. Benis, Reinhart, Ferrão (2017) 'Development of a simulation-based decision support workflow for the implementation of Building-Integrated Agriculture (BIA) in urban contexts', Journal of Cleaner Production 589-602

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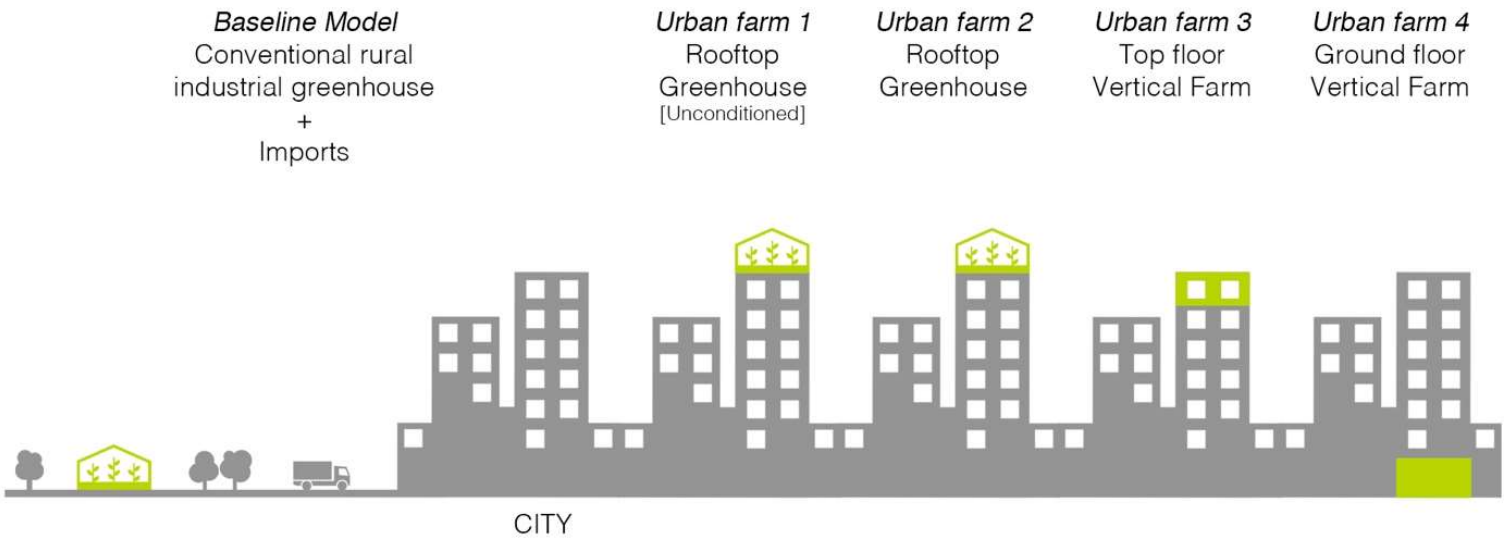
BIA in Parque das Nações [Simulated scenarios]

… compared to

Baseline. Current supply chain for tomatoes
UF 1. Low-tech rooftop greenhouse



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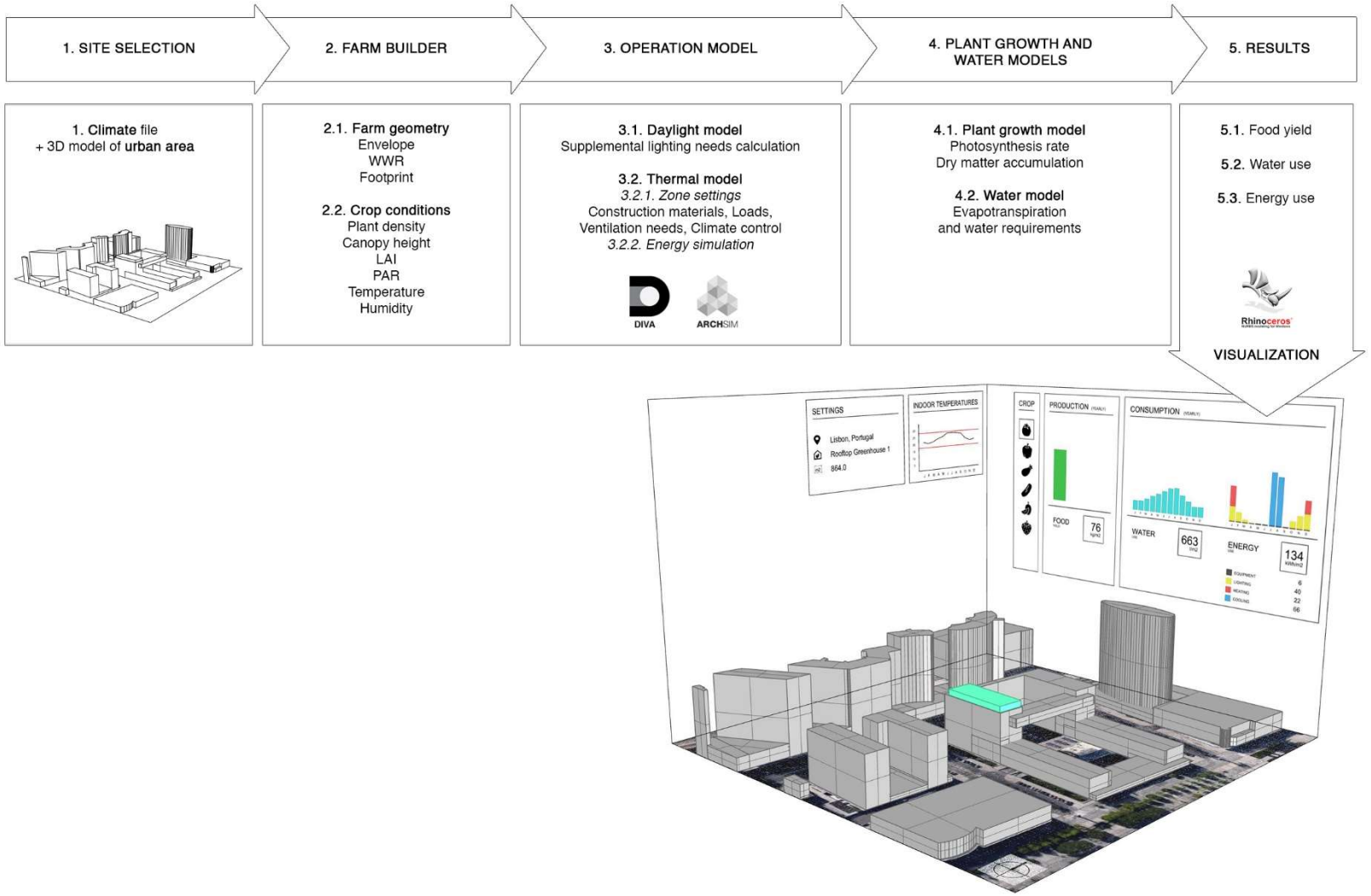
Simulation workflow



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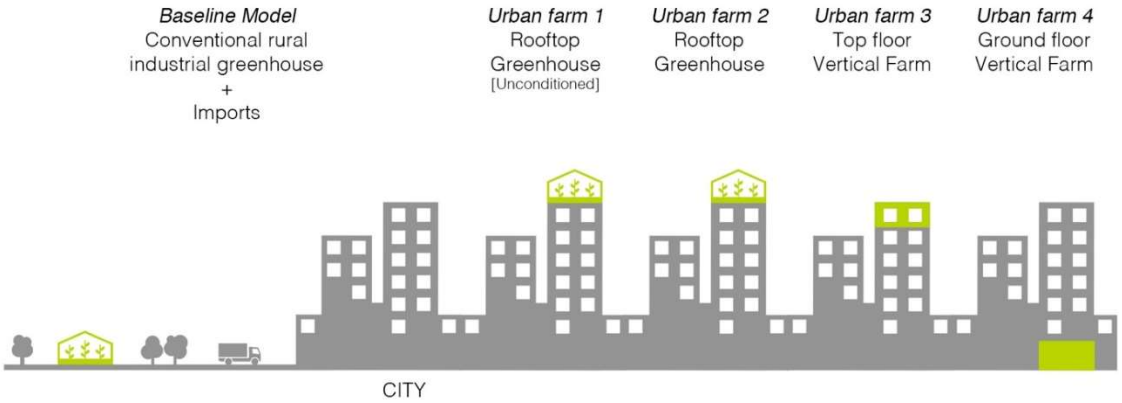
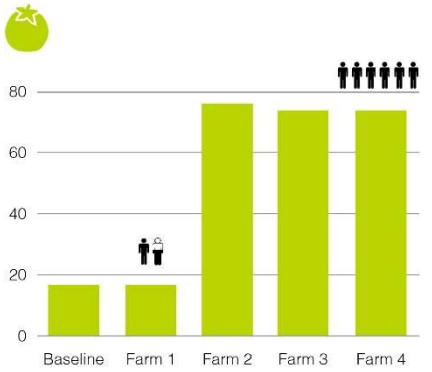
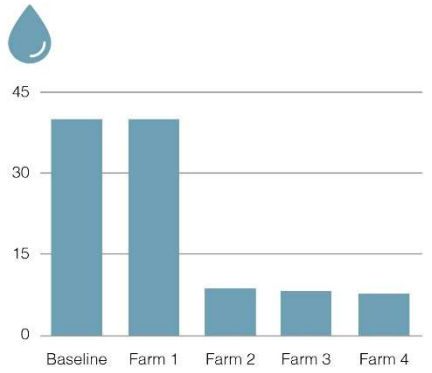
BIA in Parque das Nações [Yields and water use]



Yield *[kg/m²/y]*



Water use *[l/kg]*



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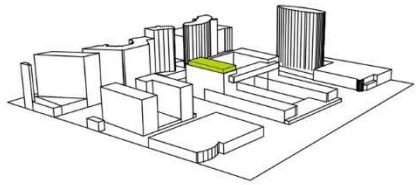
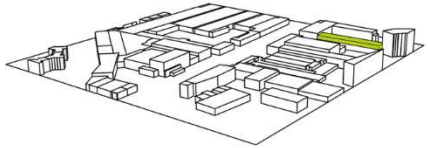
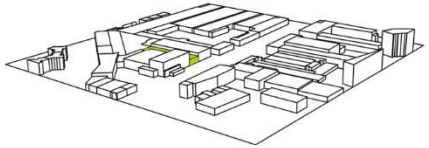
BIA in Parque das Nações [Energy use]



Urban Farm 2



Urban Farm 3



Urban Farm 4

	Urban Farm 2	Urban Farm 3	Urban Farm 4
Equipment	6	6	6
Lighting	21	72	232
Heating	19	9	0
Cooling	78	0	16
Loads [kWh/m²]	124	87	254
Use [kWh/m²] *	**53**	**81**	**242**

* Heating COP = 3.1; Cooling COP = 3.93

Paper. Benis, Reinhart, Ferrão (2017) 'Development of a simulation-based decision support workflow for the implementation of Building-Integrated Agriculture (BIA) in urban contexts', Journal of Cleaner Production 589-602

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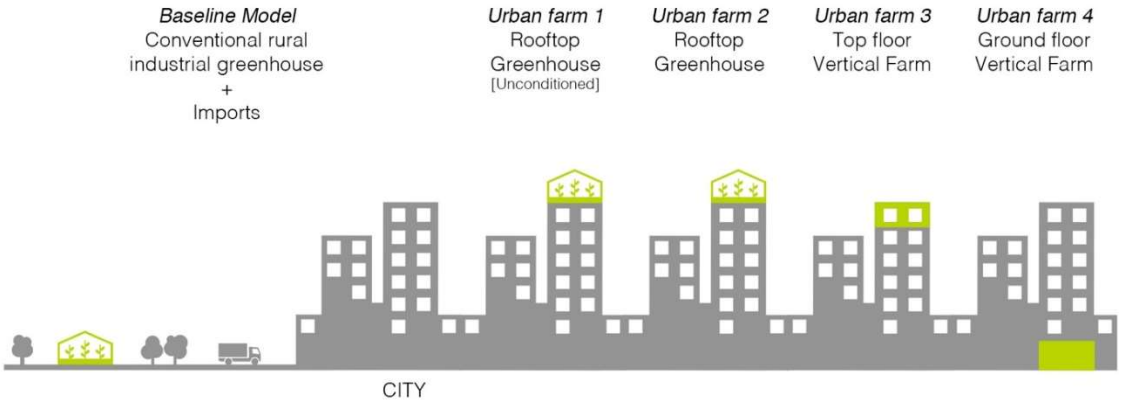
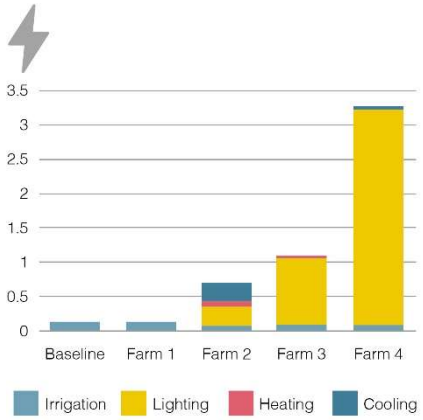
BIA in Parque das Nações [Carbon emissions]

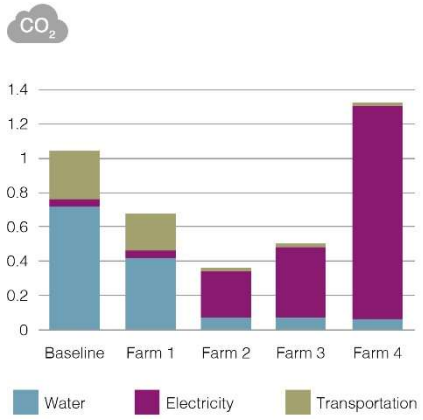


			Baseline	*Farm 1*	*Farm 2*	*Farm 3*	*Farm 4*
	Water use	[l/kg]	40.00	40.00	8.70	8.30	7.70
	GHG emissions	[kgCO_2eq/kg]	0.716	0.417	0.07	0.07	0.06
	Energy use	[kWh/kg]	0.130	0.130	0.697	1.095	3.270
	GHG emissions	[kgCO_2eq/kg]	0.049	0.049	0.264	0.415	1.239
	Transportation	[tkm]	0.556	0.419	0.03	0.03	0.03
	GHG emissions	[kgCO_2eq/kg]	0.278	0.210	0.015	0.015	0.015
CO_2	**TOTAL**	**[kgCO_2eq/kg]**	**1.042**	**0.679**	**0.352**	**0.500**	**1.319**

Operational energy *[kWh/kg]*



GWP *[kgCO2eq/kg]*



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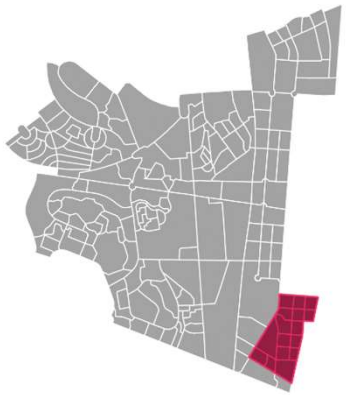
Lessons learned

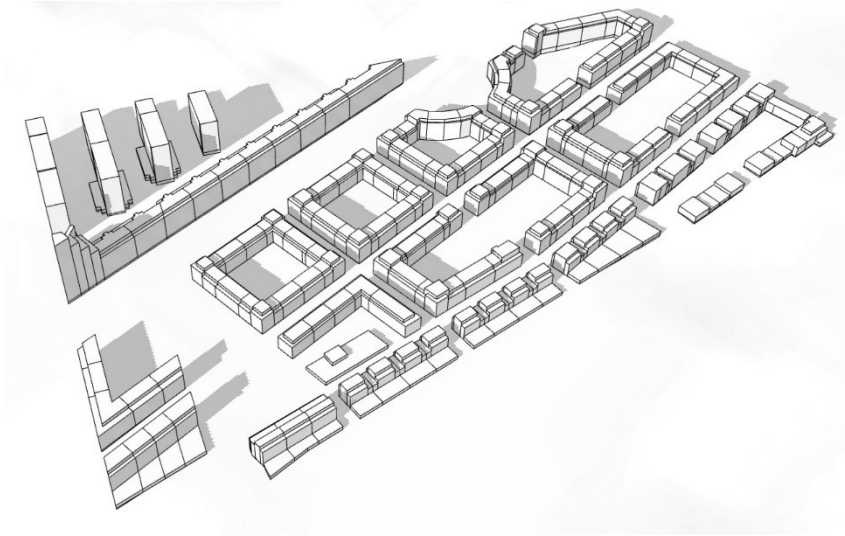
The aim of this holistic approach is to guide stakeholders (local authorities, urban planners, entrepreneurs) through decision-making on the potentialities of implementing BIA in a given neighborhood while maximizing crops yields and minimizing water and energy consumption.

- *BIA is claimed to be sustainable for cutting food miles but farms can be energy-intensive and may not be appropriate to any location.*
- *High-tech urban farms can be more sustainable than conventional unconditioned greenhouses under Mediterranean climates.*
- *Largest share of CO_2 emissions are related to electricity. This can be mitigated by associating clean renewable energy sources to these systems.*

Paper. Benis, Reinhart, Ferrão (2017) 'Development of a simulation-based decision support workflow for the implementation of Building-Integrated Agriculture (BIA) in urban contexts', Journal of Cleaner Production 589-602

BIA in Parque das Nações [Self-sufficiency?]



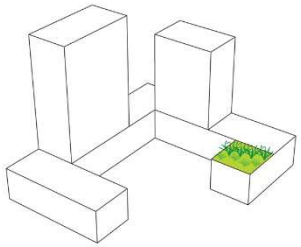


CABO RUIVO

Residential neighborhood

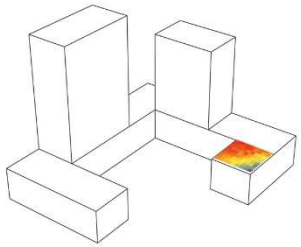
Population 2,975 residents

Available Rooftop Area 71,050 m²



(1)

Identify potential farming area



(2)

Perform solar radiation analysis

Average solar radiation *[kWh/m²/y]*	Farm Score *[%]*
<850	0
850-999	17
1,000-1,149	33
1,150-1,299	50
1,300-1,449	67
1,450-1,599	83
1,600	100

(3)

Only install a hydroponic greenhouse if average solar radiation of area is above **1,150 kWh/m²/y**

Class Assignment. 'Farm score' from: Benis, Turan, Tolgay (2016) 'Alfacinha', Urban modeling class assignment at MIT, Spring term 2016, Prof.: C. Reinhart

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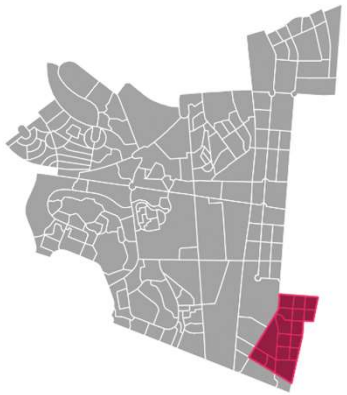
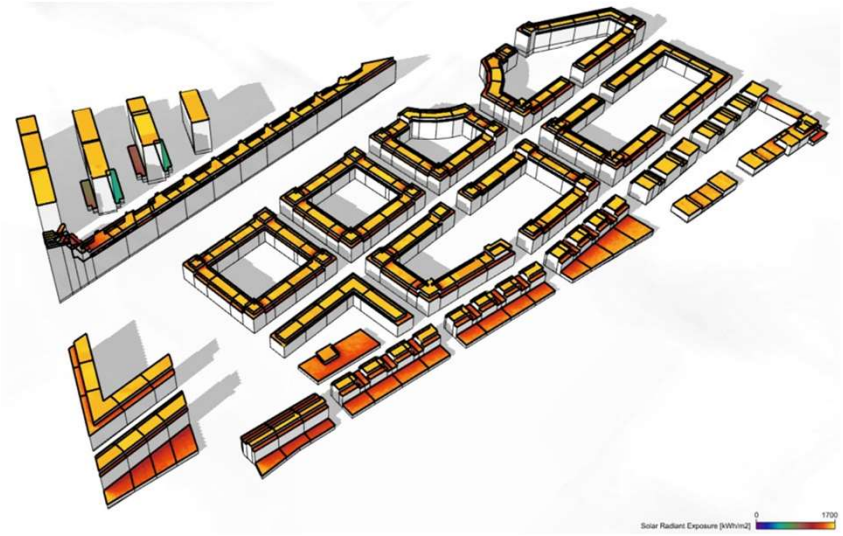
BIA in Parque das Nações [Self-sufficiency?]

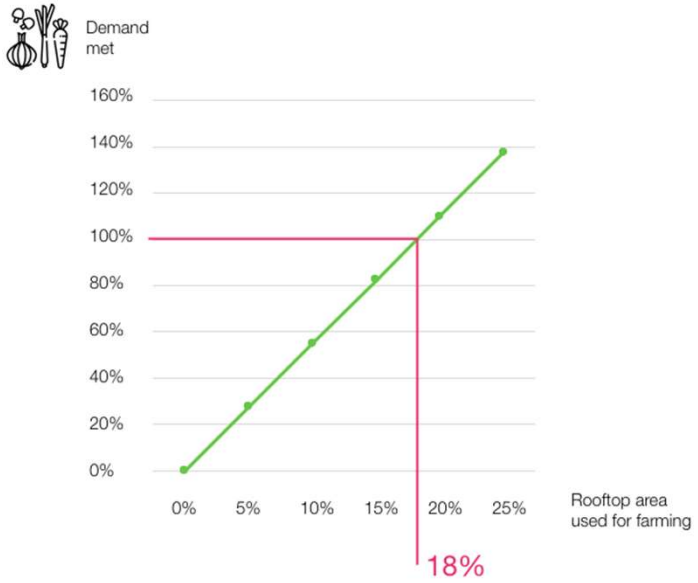


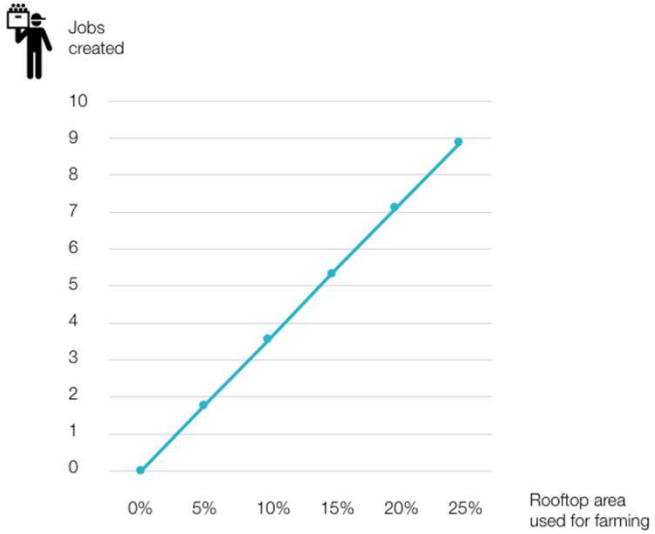


CABO RUIVO
Residential neighborhood

Population 2,975 residents
Available Rooftop Area 71,050 m^2

Avg radiation 1,419 $kWh/m^2/y$





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Competing rooftop uses [Food vs. Energy]

ROOFTOPS. Large unused urban areas with direct exposure to sunlight.

Food production

Reduces food miles

Provides local jobs

Energy generation

Provides clean energy

Creates jobs

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

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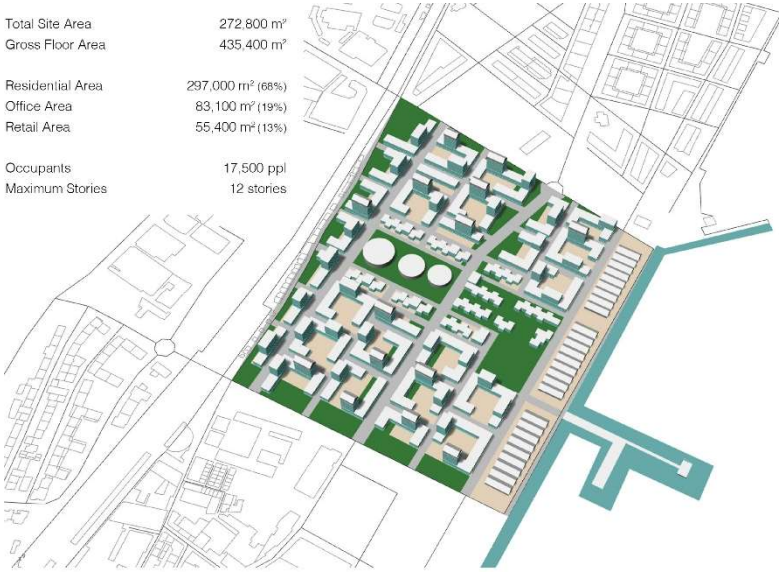
Comparing alternative uses [LISBON]



CAIS DA MATINHA

Mixed-use neighborhood

Available Rooftop Area 41,958 m^2

Site design from: Benis, Turan, Tolgay (2016) 'Alfacinha', Class project at MIT, Spring term 2016

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

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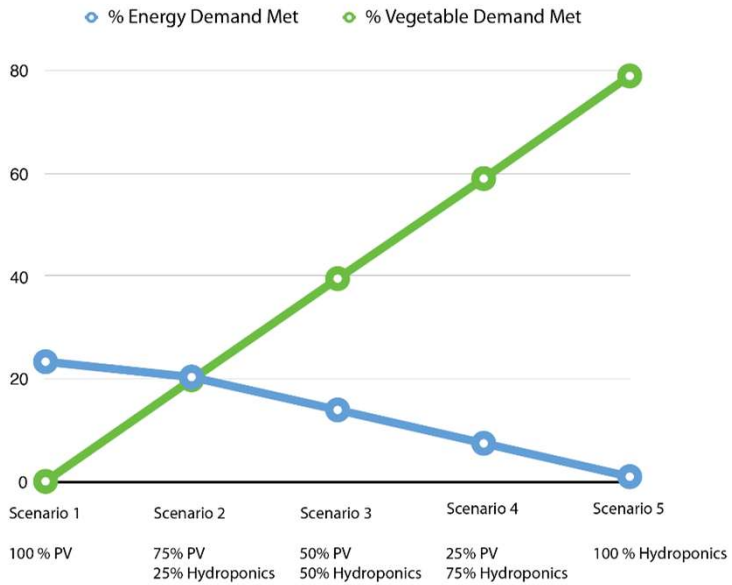
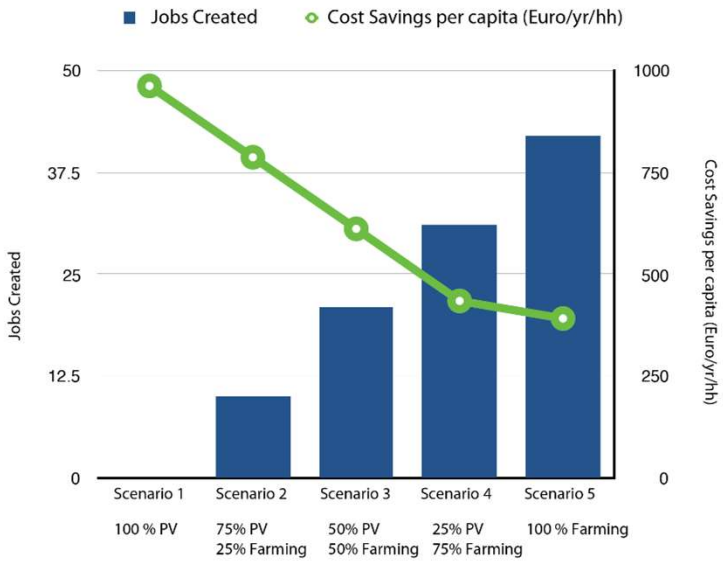
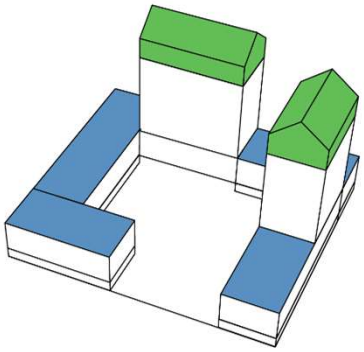
Level of Self-Sufficiency [CAIS DA MATINHA]







Chosen Scenario:

35.2 % Hydroponic Greenhouses
(all high roofs for hydroponic farming)

64.8 % PV
(all low roofs)

RESULTS

% Energy Demand Met	% Vegetable Demand Met	Cost Savings	Jobs Created
16	41	752 euro/yr/hh	15

Assessment from: Benis, Turan, Tolgay (2016) 'Alfacinha', Class project at MIT, Spring term 2016

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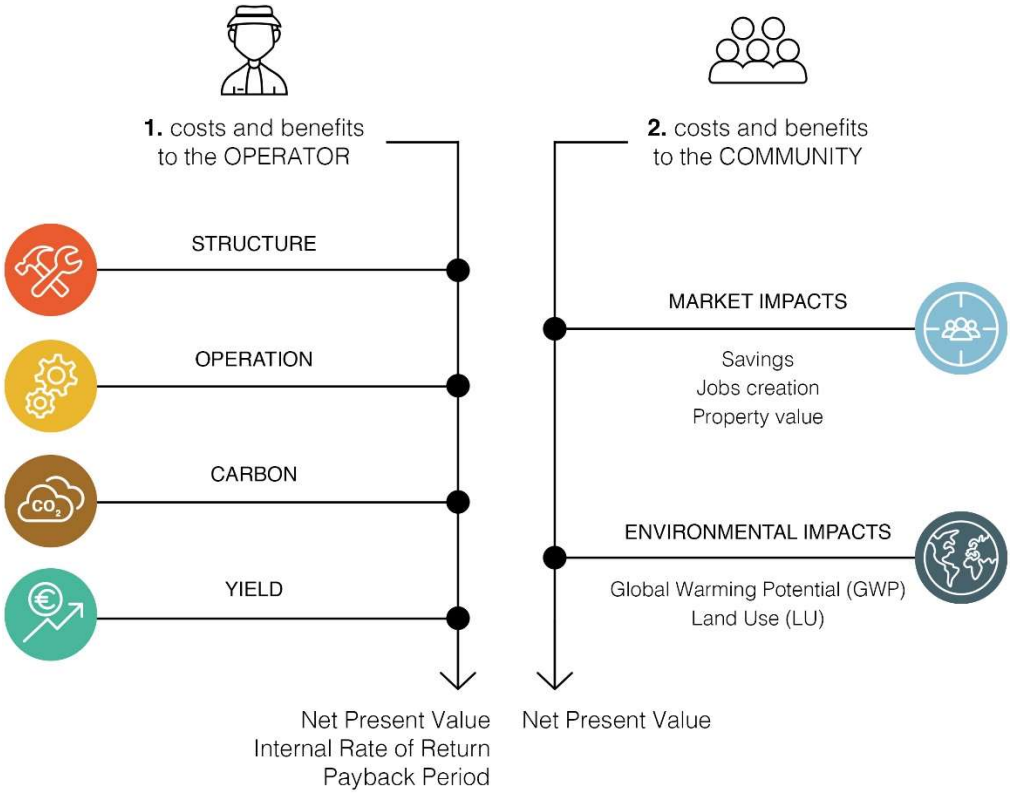
Two-level Cost-Benefit Analysis [CBA]



- *50-year Discounted Cash Flow*
- *6% discount rate*
- *2.5% annual inflation*
- *Functional unit = 1m^2 of rooftop*

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

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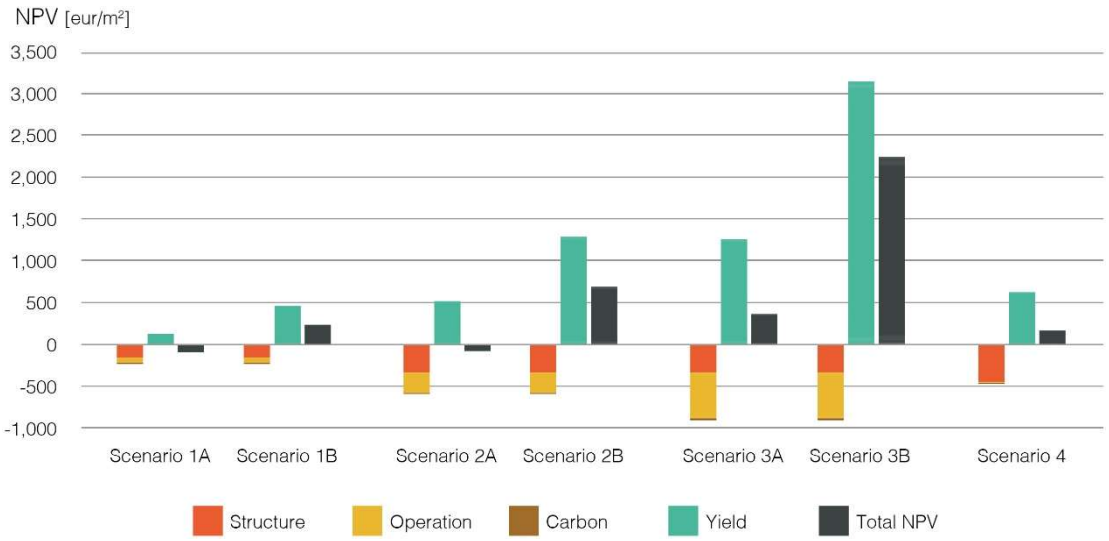
Results [Benefits for the systems' operator]



- *Food production is more beneficial than energy generation for the owner of the system.*
- *Costs of RGs are higher for the operator but produce yield is higher and leads to more profit.*

Scenario		*NPV* [€/m²]	*IRR* [%]	*1st Payback Year*
SC 1: GR	A. LFSC B. SFSC	-96.44 233.29	0 16	30 8
SC 2: LTBIA	A. LFSC B. SFSC	-77.99 690.30	1 36	// 4
SC 3: HTBIA	A. LFSC B. SFSC	360.62 2,237.46	23 96	6 3
SC 4: BIPV		163.40	11	10

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

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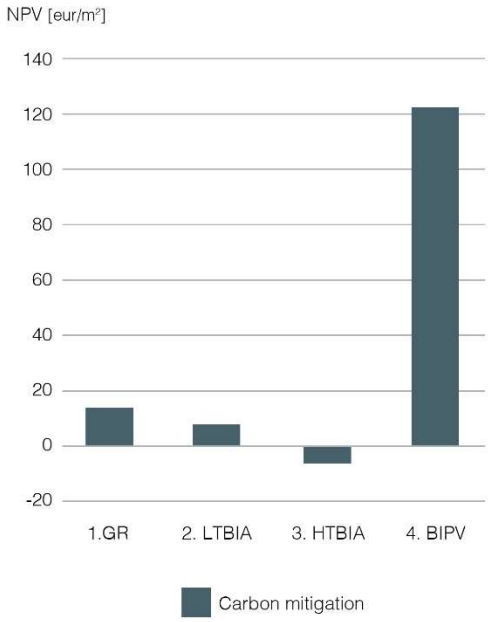
Results [Benefits for the community]



- *Food production is more beneficial than energy generation for the local community.*
- *RGs are also more beneficial to the community, serving as an abundant source of localized produce and creating local jobs.*

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

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Policy recommendations

Rooftops —currently an unused resource — can be activated as a valuable amenity for our cities. Based on CBA assessments, policy may include the following actions.

- *Including productive rooftops into urban resilience plans (e.g., zoning codes targeting minimum levels of self-sufficiency of neighborhoods).*
- *More flexible urban codes (e.g., exemptions from height and area limitations).*
- *Financial instruments (e.g., municipal subsidies and loan programs for retrofits; subsidized water and energy; real estate tax reductions).*
- *Fostering R&D and product quality certification.*

Paper. Benis, Turan, Reinhart, Ferrão (2018) 'Putting rooftops to use – A Cost-Benefit Analysis of food production vs. energy generation under Mediterranean climates', Cities, In Press

Summary

- *We need effective urban data plans that collect and quality control information about the city. Access to select household energy data is critical.*
- *A UBEM based of this data can help define energy reduction targets and formulate concrete policy measures. Focus on load reduction and smart controls implementation critical.*
- *Climate change and urban densification will lead to significant adoption of air condition along with increased peak loads.*
- *Urban data model can also help define objective property taxes to consider environmental benefits of a building.*
- *Rooftop can be used for multiple uses beyond PV and SHW including food production.*
- *We hope that you will challenge us on our finding and share critical challenges that you face today.*

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