Innovation and Future Best Practices in the Environmental Impact Analysis of Buildings and Cities

Diego Ibarra, PhD
Harvard University
Managing Partner
EA Buildings

EA BUILDINGS

Harvard University

POLÍTICA ECO URBANISMO PLAN DE ACCIÓN 2024

BCS BOGOTÁ CLIMATE SUMMIT
BOGOTÁ CUMBRE DEL CLIMA
Septiembre 20-23, 2015

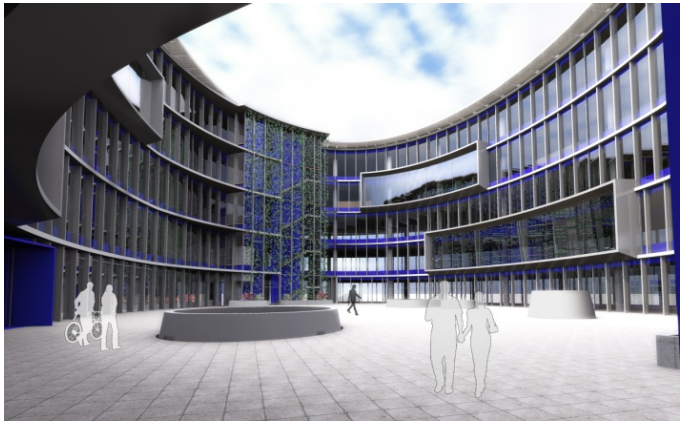
Agenda

- ✓ **Síntesis de prácticas actuales de evaluación del impacto ambiental de edificios**

- ✓ **Innovación y futuras tendencias en optimización del performance ambiental y económico de:**
  - ❑ Edificios
  - ❑ Barrios y Ciudades
  - ❑ Infraestructura

KAUFMANN – MERCEDES BENZ

Mercedes-Benz



OBJETIVOS DE SUSTENTABILIDAD – Mercedes Benz

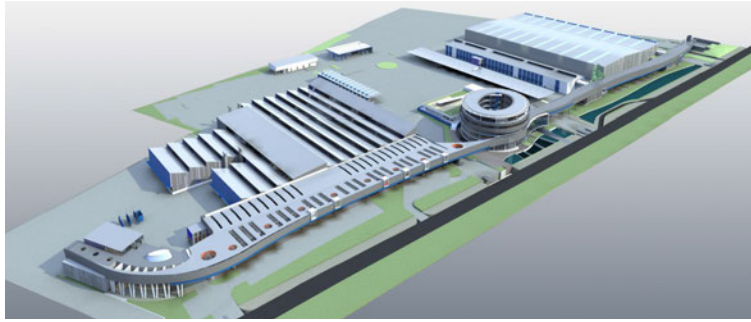
Metas de sustentabilidad

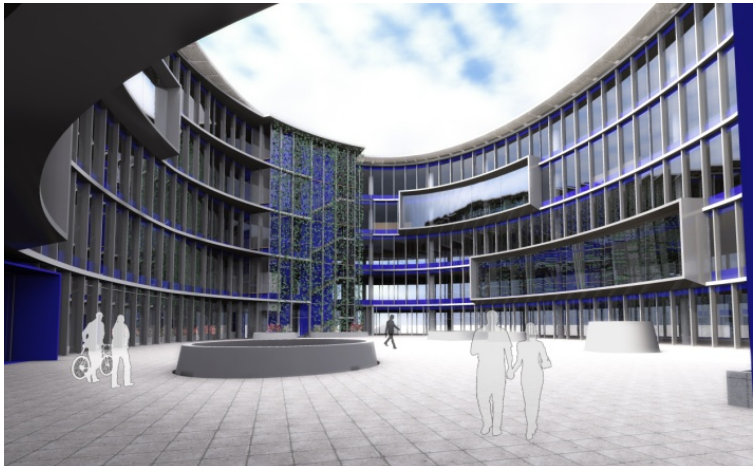
-Baja **COSTO DE MANTENCIÓN**

-Bajo riesgo **OPERACIONAL**

-Bajo consumo **ENERGÉTICO**

-Mejorar el **CONFORT** (situación actual)





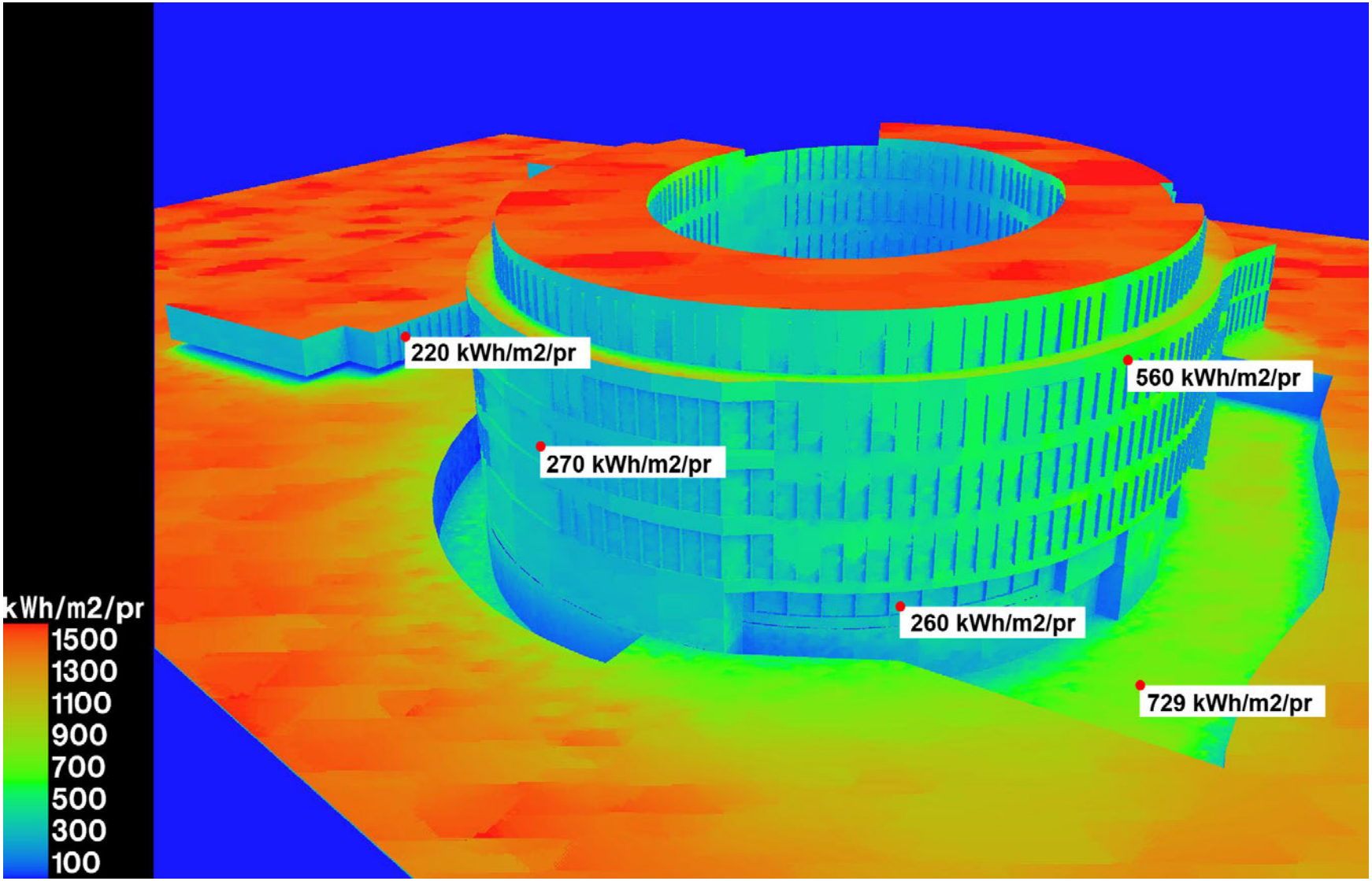
Métricas de sustentabilidad

Porcentaje de ahorro:

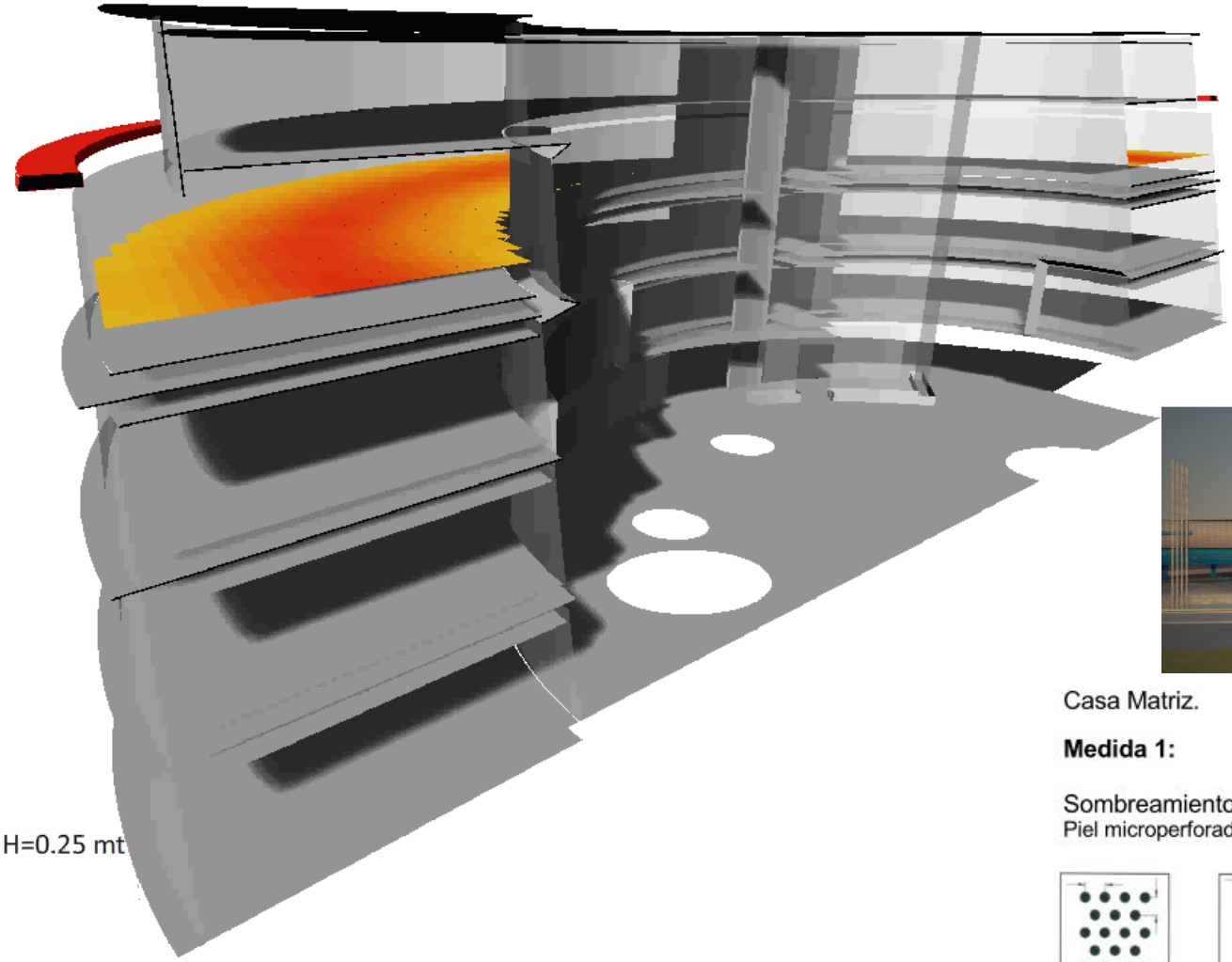
- Energético (EUI)	>**20%**
- Iluminacion Natural (DA)	**>70%**
- Agua (lts/yr)	>**30%**
- Confort térmico	**a definir**
- Accesibilidad y transp.	**a definir**

Retorno de la inversión <**12 años**

ANÁLISIS DE DIAGNOSTICO DEL DISEÑO INICIAL



Radiacion solar

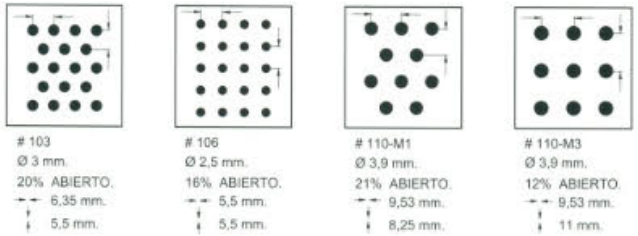


H=0.25 mt

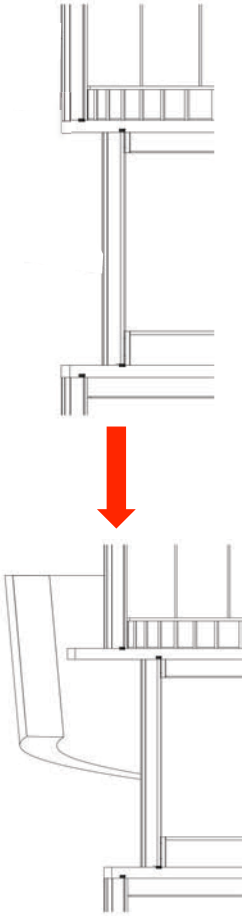
Casa Matriz.

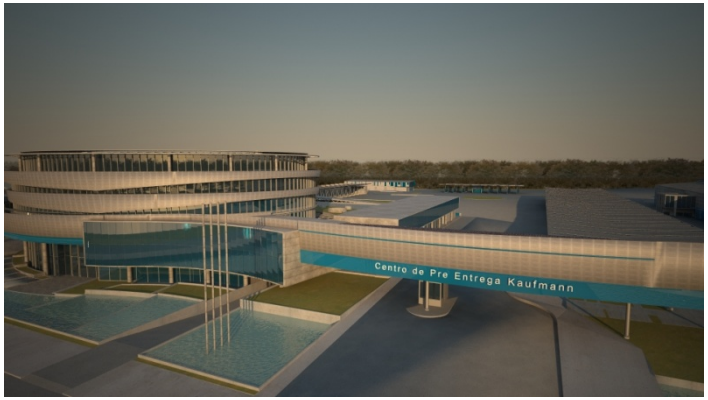
Medida 1:

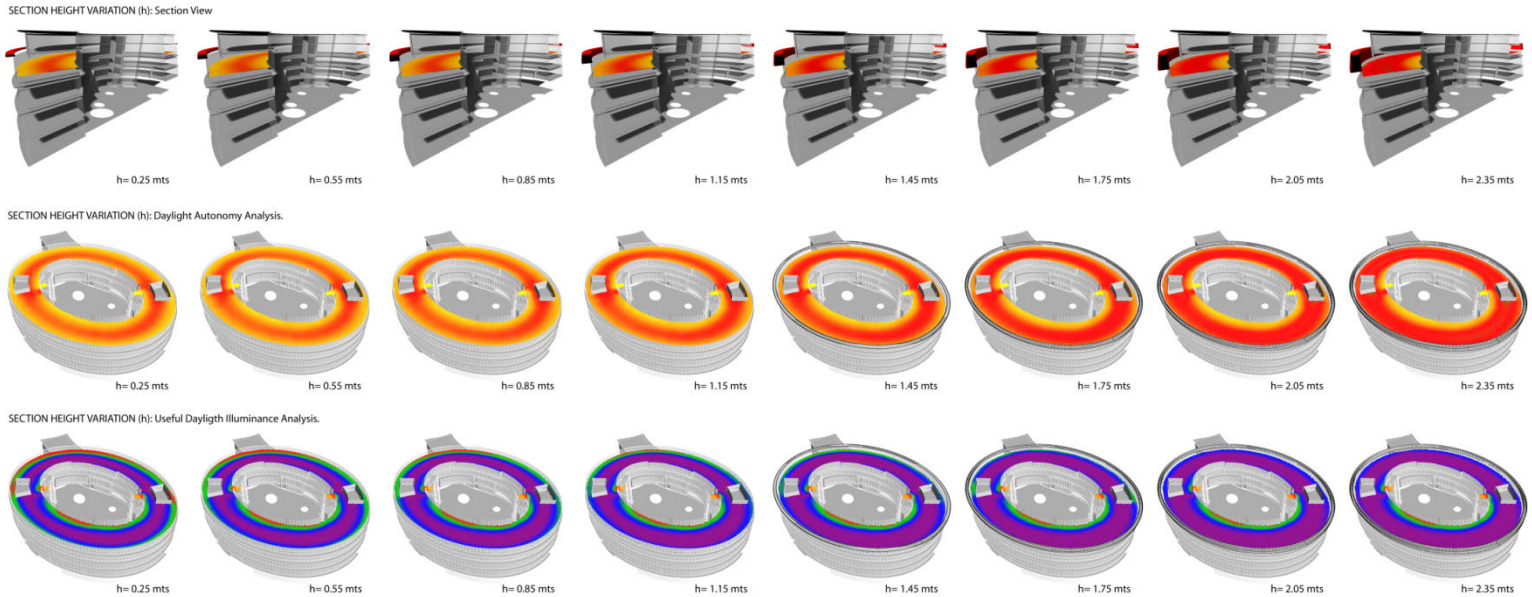
Sombreamiento fachada.
Piel microperforada (screen Panel H.D.) 20% abierto



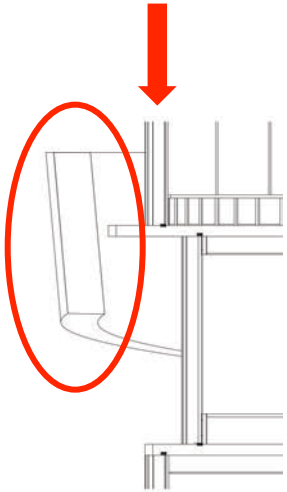
Iluminación Natural



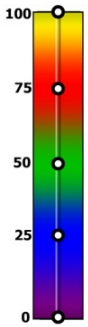




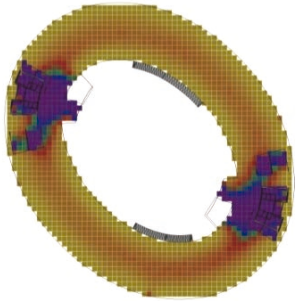
CASA MATRIZ– OPTIMIZACIÓN DE CINTA MICROPERFORADA EXTERIOR



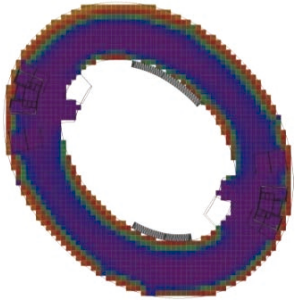
Iluminación Natural



Tvis:72%

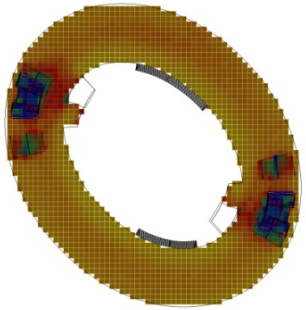


DA-400 / Sin pro

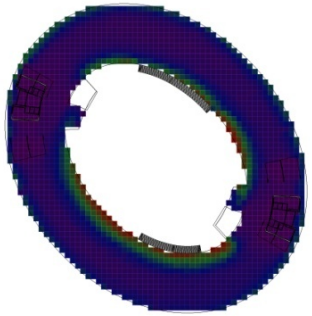


DUI-2000 / Sin pro

Tvis:50%

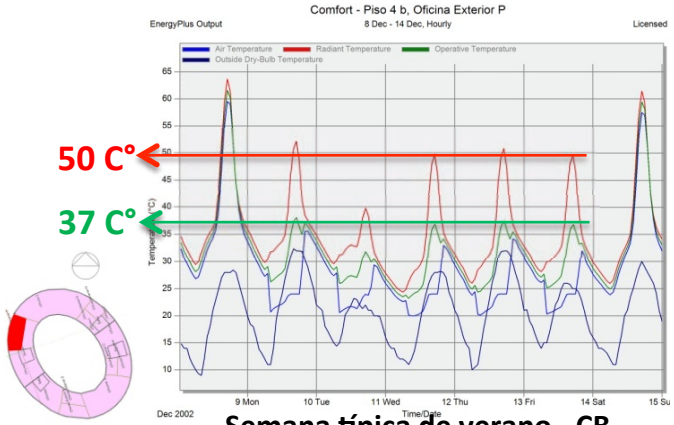


DA-400 / Con pro

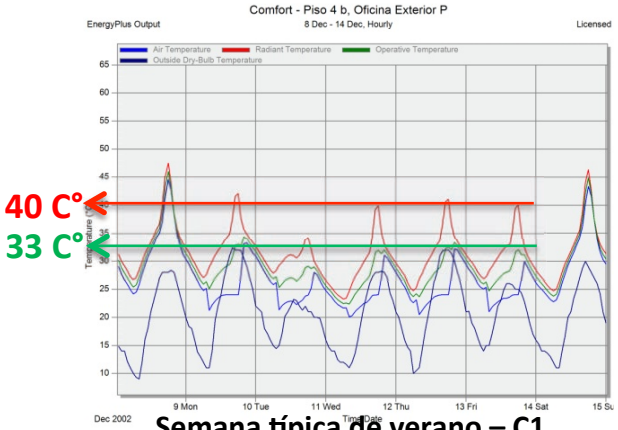


DUI-2000 / Con pro

Confort Térmico



Semana típica de verano - CB



Semana típica de verano – C1

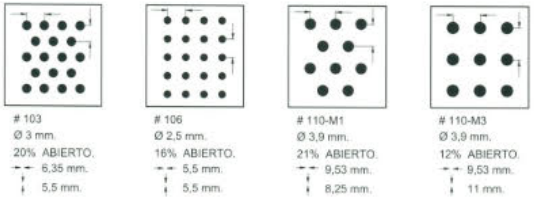
* Estos ahorros corresponden a valores estimados considerando una serie de condiciones de borde. Debido a esto, deben tomarse como un valor referencial para tener un orden magnitud y entender cuales estrategias son más relevantes que otras, tomando en consideración también los montos de inversión involucrados. No deben considerarse como una predicción exacta del consumo energético que tendría el edificio, dado que las condiciones de borde variarán durante la operación de éste. **Tarifa kWh eléctrico: $80 / Tarifa m3 de gas: $557**

Retorno economico

Casa Matriz.

Medida 1:

Sombreamiento fachada.
Piel microperforada (screen Panel H.D.) 20% abierto



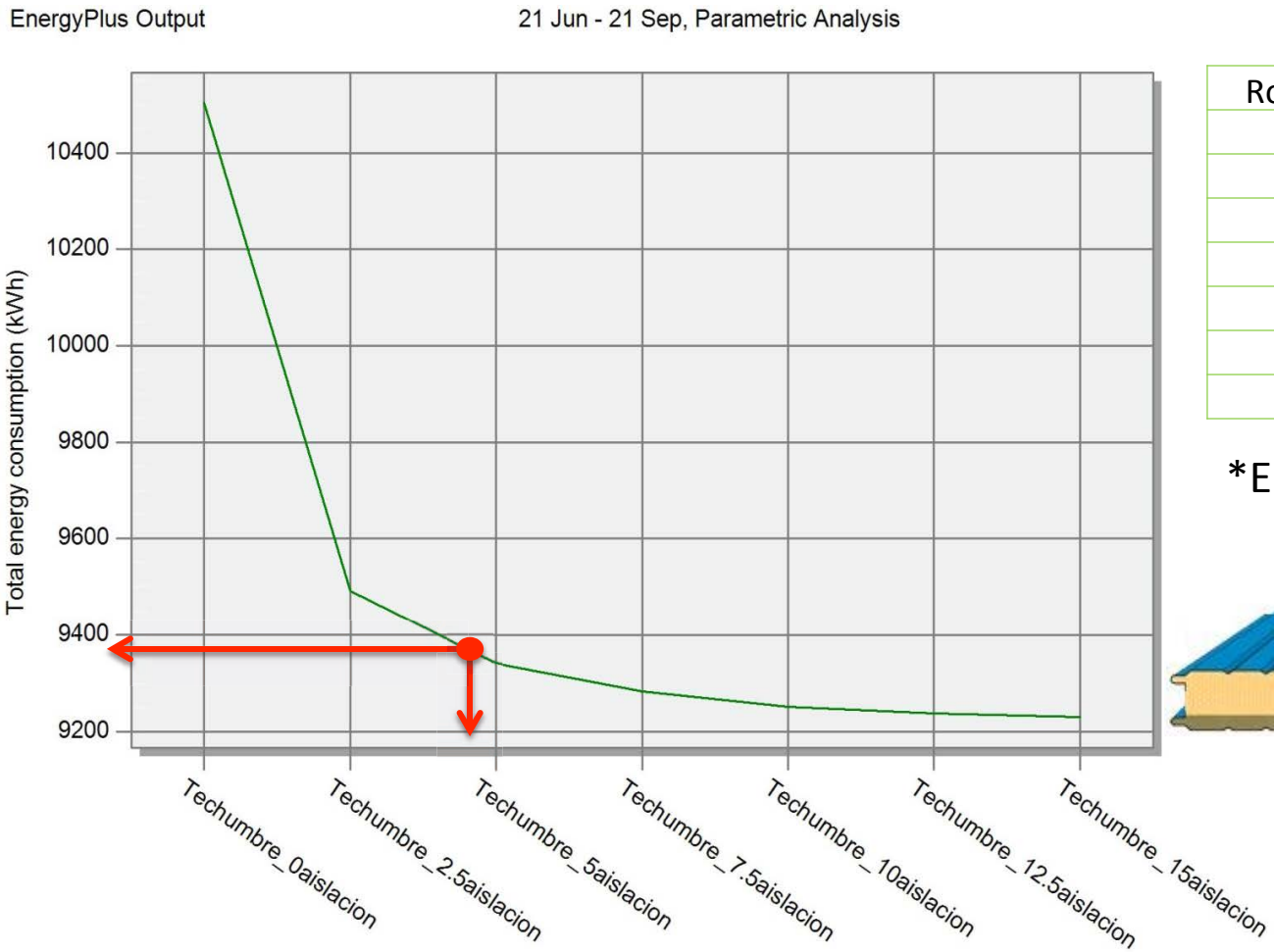
COSTO IMPLEMENTACIÓN	AHORRO ANUAL	PAY-BACK
$ 63.995.984	$ 5.463.166	11

Medida 2:

Mejorar envolvente acristalada del caso base.
Caso base termopanel estandar:
Caso optimizado cristal con doble capa de plata 50% Tvis U: 1,6

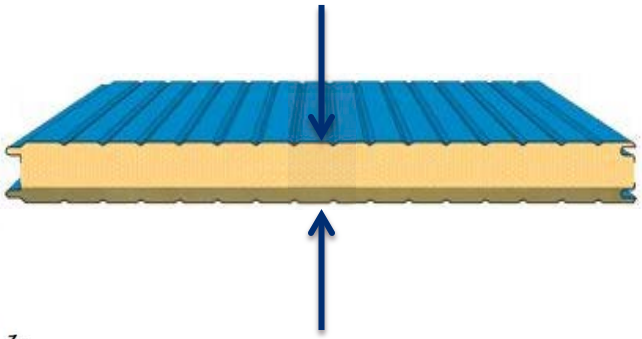
COSTO IMPLEMENTACIÓN	AHORRO ANUAL	PAY-BACK
$ 37.400.097	$ 8.167.270	4,6

OPTIMIZACIÓN PARAMETRICA DE ENVOLENTE



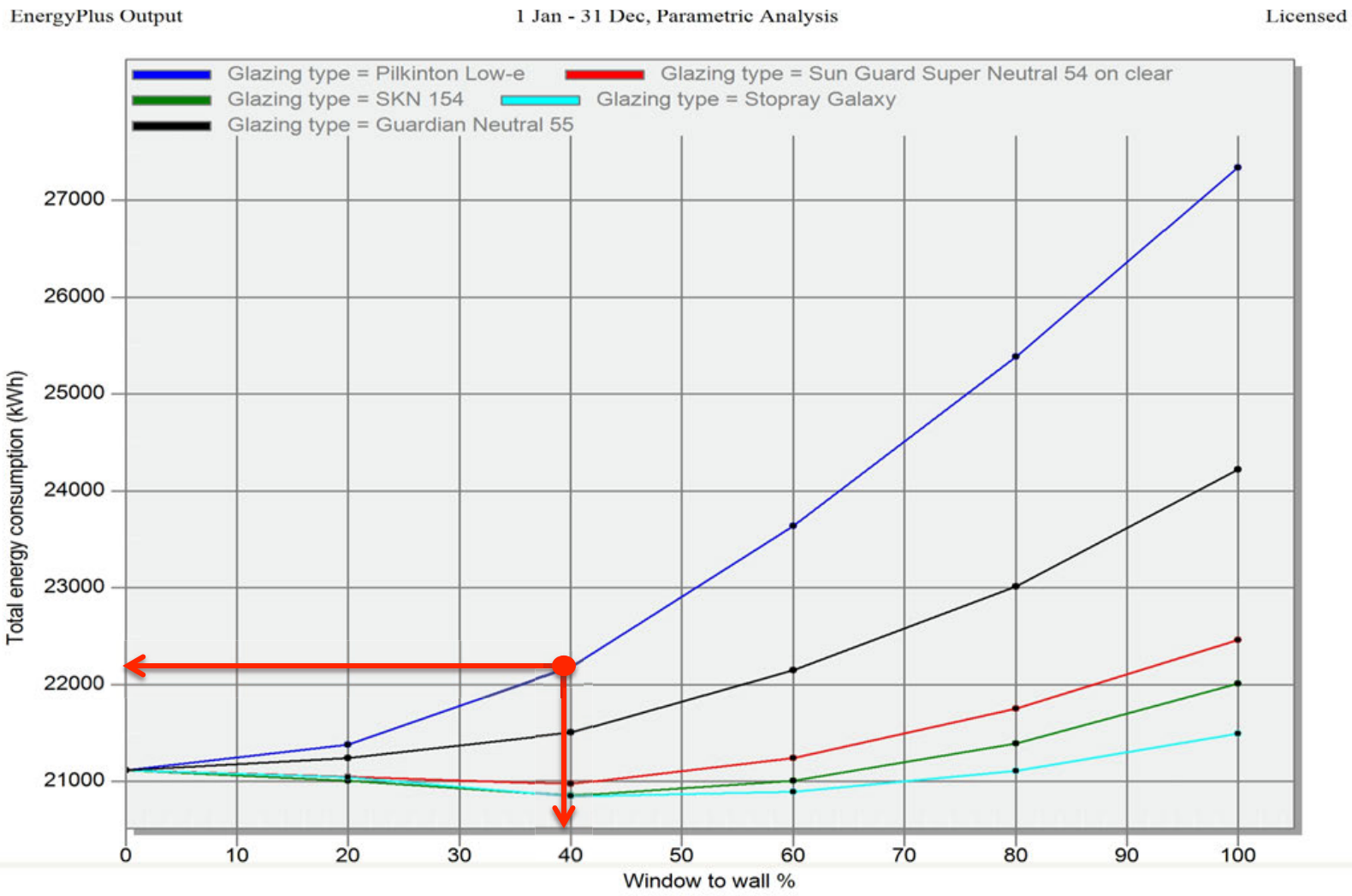
Roof insulation* [cm]	U [W/m2K]
0	3.807
2.5	1.094
5	0.639
7.5	0.451
10	0.349
12.5	0.284
15	0.24

*EPS

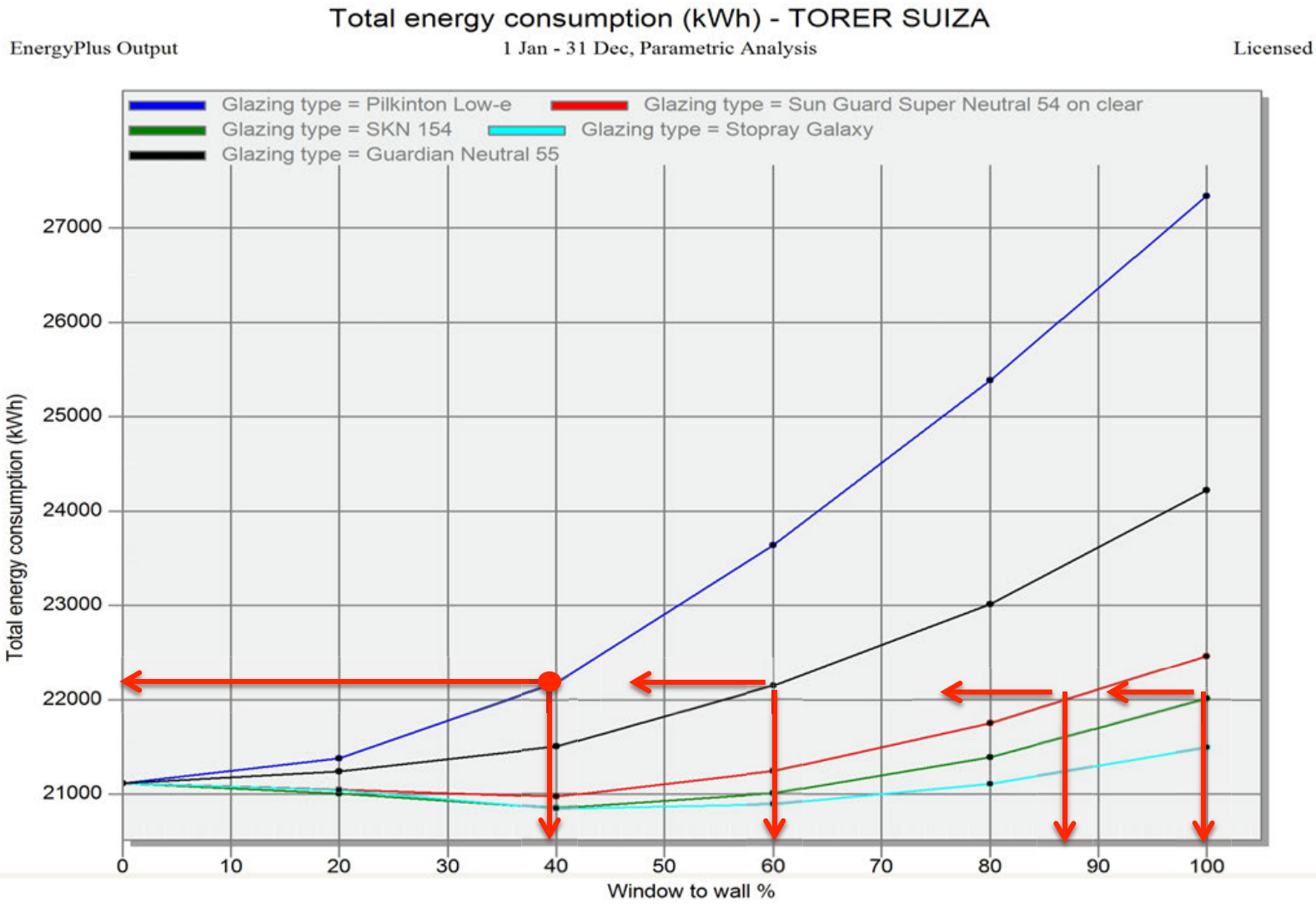


ENERGY ANALYSIS– Parametric runs for roof insulation

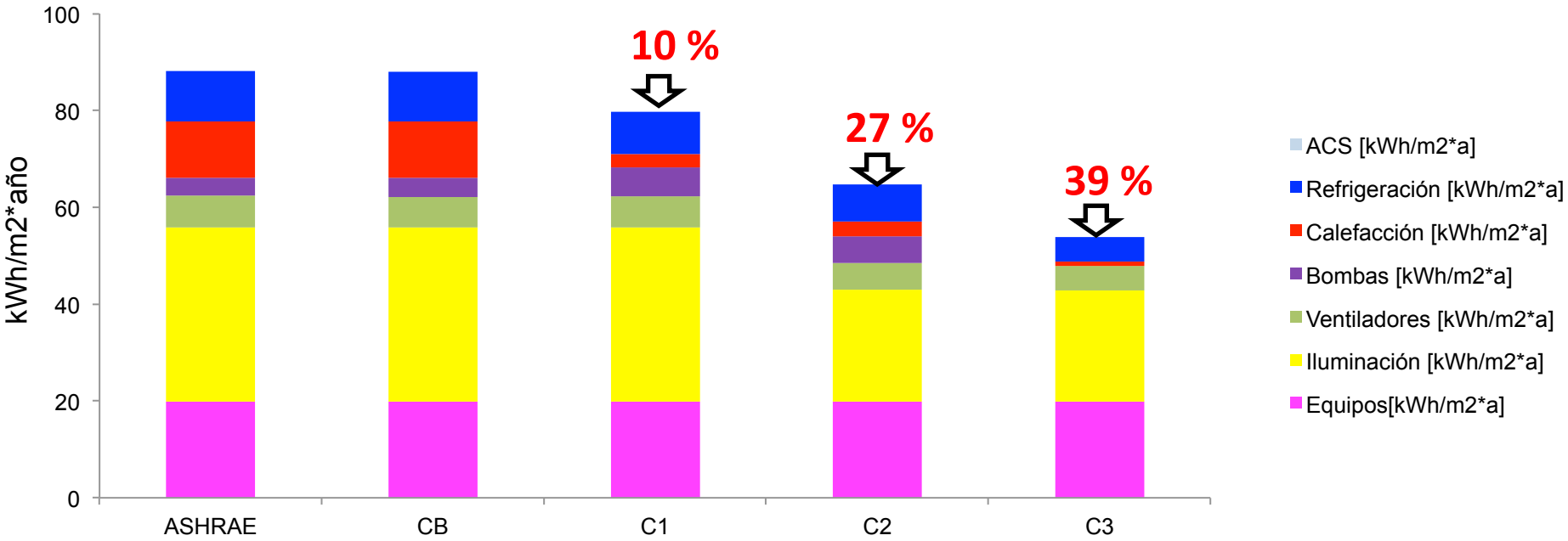
OPTIMIZACIÓN PARAMETRICA DE ENVOLENTE



OPTIMIZACIÓN PARAMETRICA DE ENVOLENTE

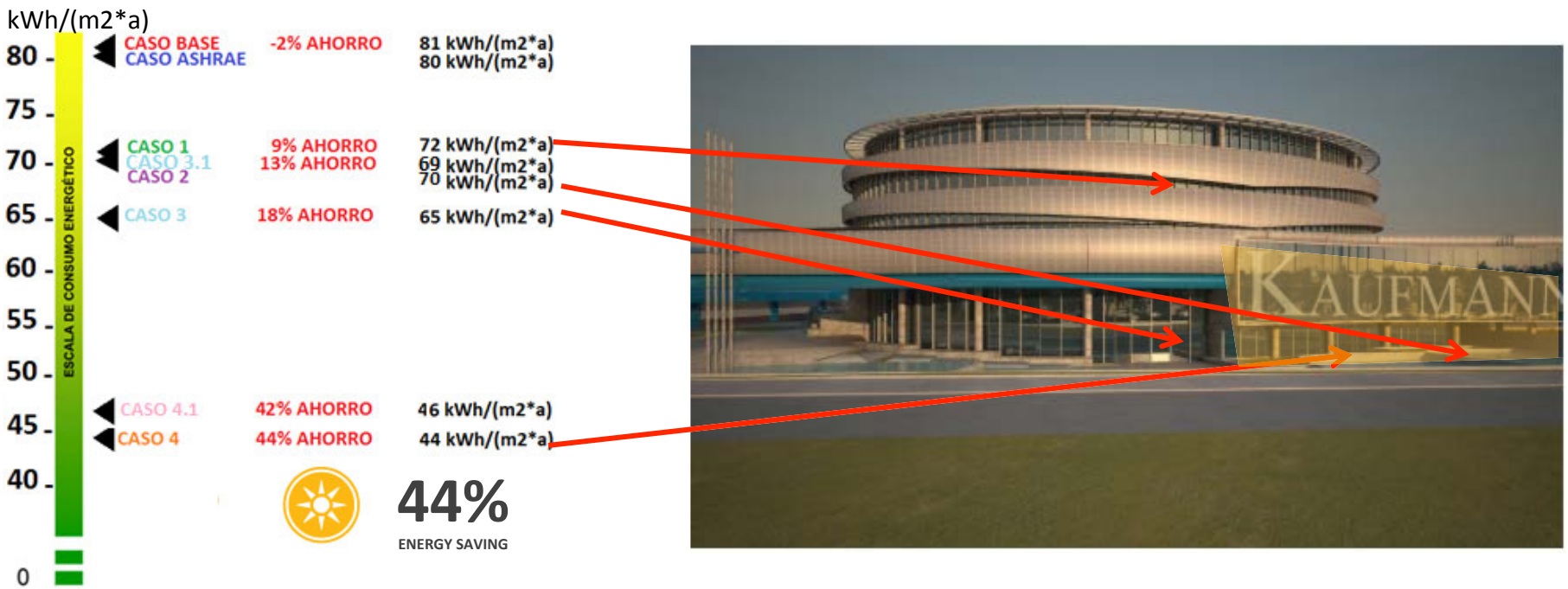


COMPARACIÓN DE VARIANTES DE OPTIMIZACIÓN



Consumos	ASHRAE	CB	C1	C2	C3	C4
Equipos[kWh/m2*a]	20	20	20	20	20	20
Iluminación [kWh/m2*a]	36	36	36	36	23	23
Ventiladores [kWh/m2*a]	6	6	6	6	6	5
Bombas [kWh/m2*a]	3	4	4	6	5	0
Calefacción [kWh/m2*a]	7	12	12	3	3	1
Refrigeración [kWh/m2*a]	10	11	10	9	8	5
ACS [kWh/m2*a]	0	0	0	0	0	0
TOTAL	82	88	88	80	65	54
Ahorro % v/s Caso Base			0%	10%	27%	39%
Ahorro % v/s Caso Ashrae		-8%	-8%	2%	21%	34%

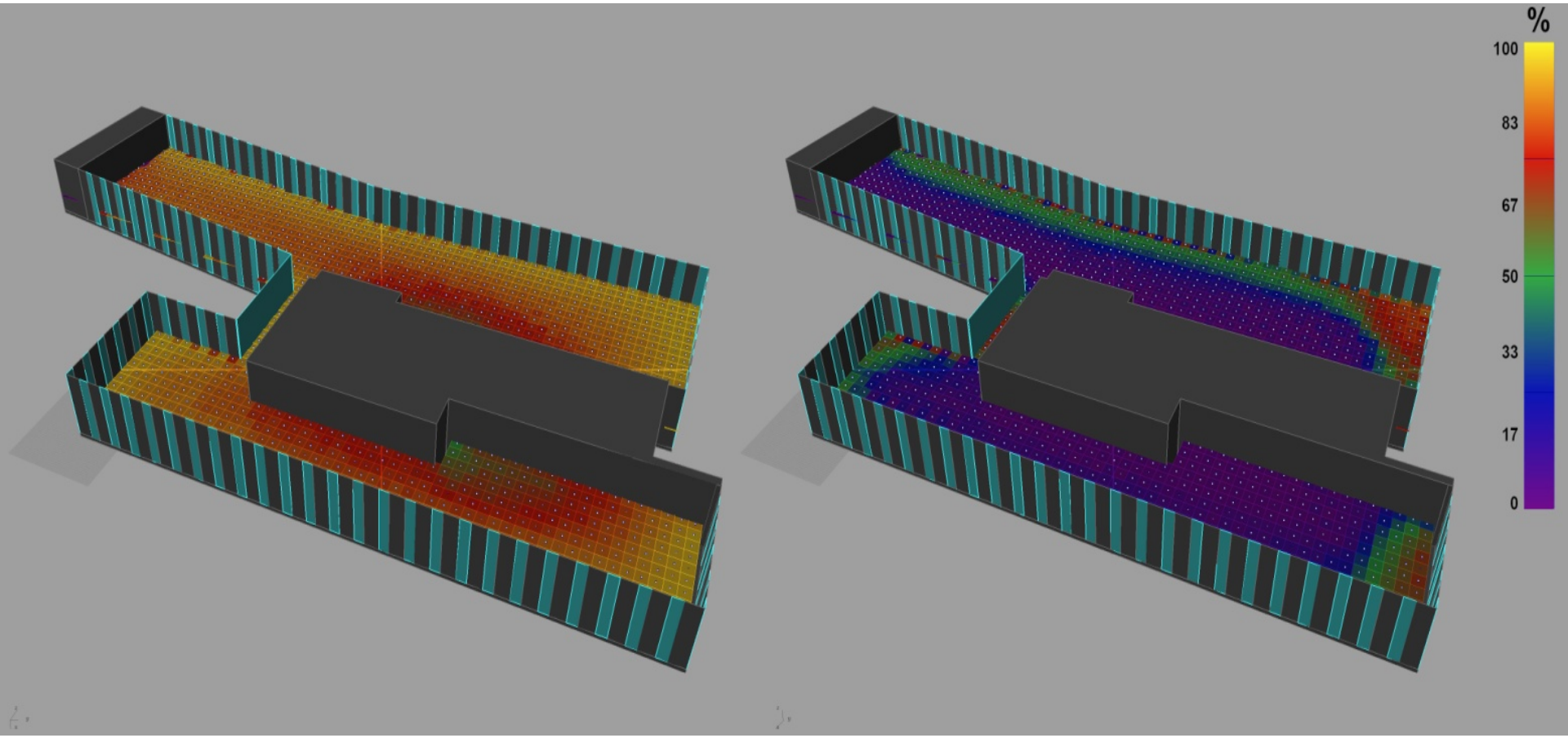
COMPARACIÓN DE VARIANTES DE OPTIMIZACIÓN



Consumos	ASHRAE	CB	C1	C2	C3	C3.1	C4	C4.1
Room Electricity [kWh/m2*a]	18	18	18	18	18	18	18	18
Lighting [kWh/m2*a]	34	34	34	34	34	34	15	14
System Fans [kWh/m2*a]	10	11	7	6	5	6	4	5
System Pumps [kWh/m2*a]	0	0	0	0	0	0	0	0
Heat Generation [kWh/m2*a]	1	2	2	3	3	2	4	3
Chiller [kWh/m2*a]	17	17	11	9	6	8	4	6
DHW	0	0	0	0	0	0	0	0
TOTAL	80	81	72	70	65	69	44	46
Ahorro v/s AHSRAE %		-2%	9%	13%	18%	13%	44%	42%
Ahorro v/s CASO BASE %			11%	14%	19%	15%	45%	43%

EDIFICIO COIHUE - DEL DISEÑO A LA OPERACIÓN

ANÁLISIS PARAMETRICO



Iluminación Natural

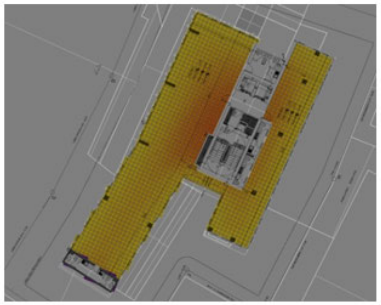


Figura 36: DA-400lux, 100% acristalamiento

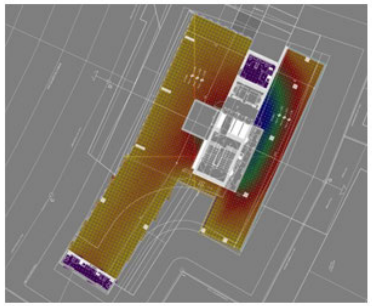
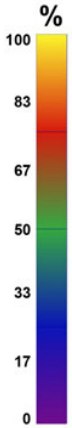


Figura 37: DA-400lux, caso 7 final



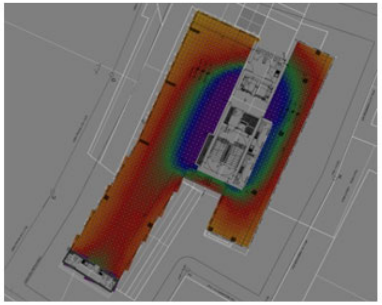


Figura 38: DUI-2000, 100% acristalamiento

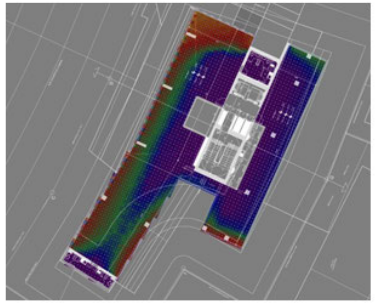
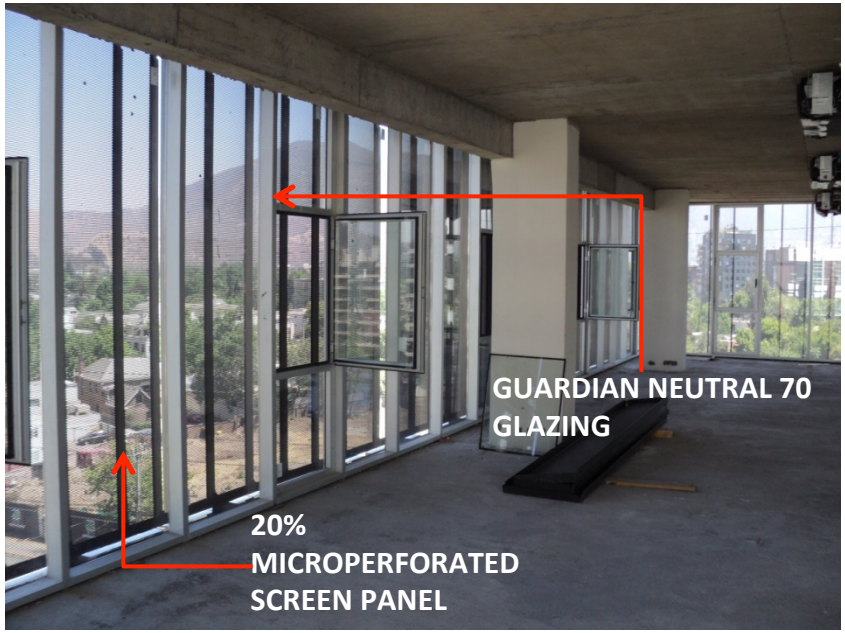


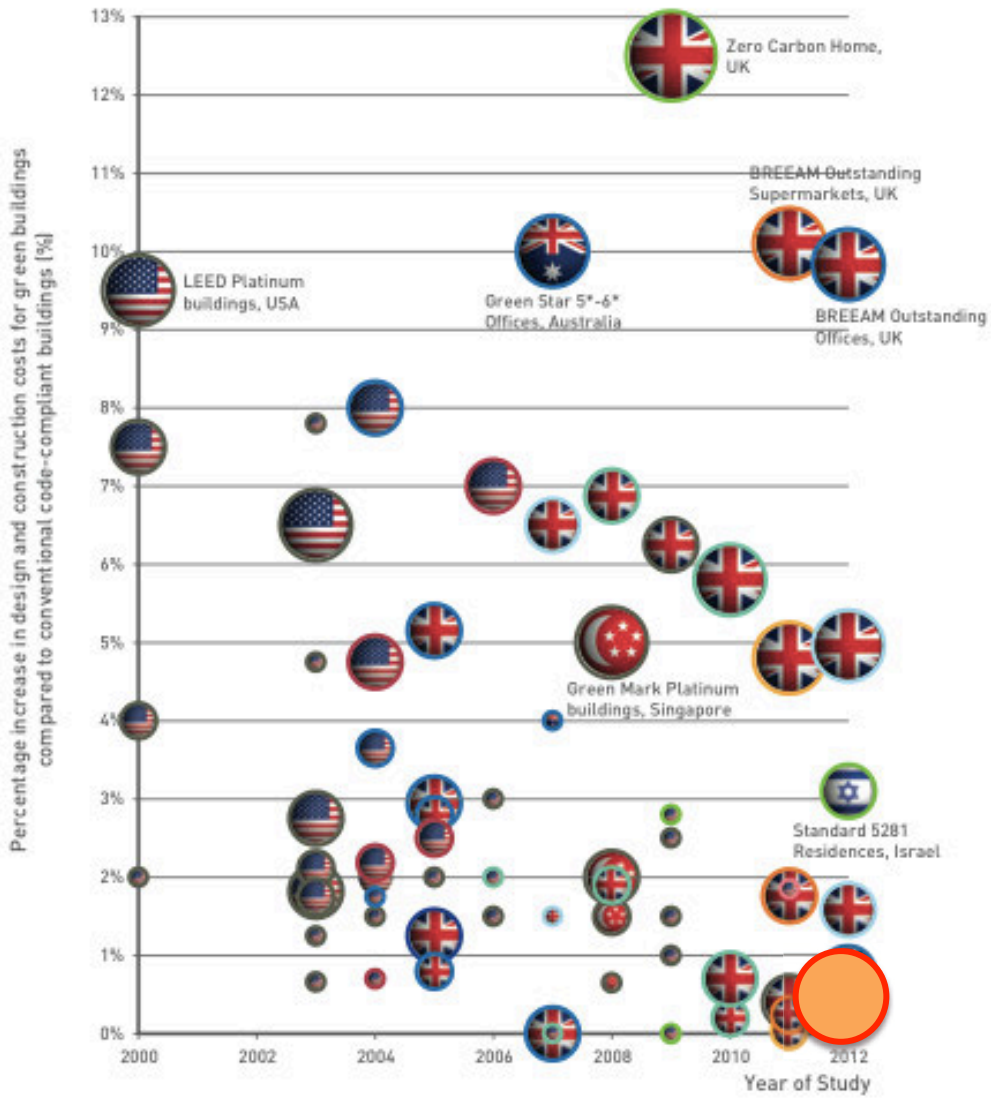
Figura 39: DUI-2000, caso 7 final



Confort Térmico

Espacios	Temperatura aire	Temperatura radiativa	Temperatura de sensación térmica
Oficinas poniente C.B	24 C°	35 C°	30 C°
Oficinas poniente C.FINAL	24 C°	29 C°	26 C°

Design optimization plays a critical role in green building costs….



WORLD GREEN BUILDING COUNCIL

(2013)

EA BUILDINGS

SELECIÓN DE PROYECTOS EN SUDAMÉRICA

OFICINAS C&S

- Edificio Ariztía, Santiago-Chile
- Edificio Amunátegui, Santiago-Chile
- Edificio Territoria el Bosque, Santiago-Chile
- Edificio Foster, Santiago-Chile
- **Edificio Costanera Lyon, Santiago-Chile**
- Edificio Moneda 1640, Santiago-Chile
- Edificio Avenida del Parque, Santiago-Chile
- Edificio Torre C - San Damián, Santiago-Chile
- Edificio Coihue, Santiago-Chile
- Edificio Moneda Bicentenario, Santiago-Chile
- Edificio Eureka, Santiago-Chile
- Edificio Armónico, Santiago-Chile
- Edificio Terrazas, Santiago-Chile
- Edificio Torre Capital, Temuco-Chile
- Edificio Citypark II, Santiago-Chile
- Edificio Hyatt-Copesa, Santiago-Chile
- Edificio Alto el Golf, Santiago-Chile
- Edificio Hyatt Place , Santiago-Chile
- Edificio Costanera Puente Suecia , Santiago-Chile

OFICINAS C&S

- Edificio Costanera Lyon II, Santiago-Chile
- Edificio Monroy, Santiago-Chile
- Edificio Núcleo-Vespucio, Santiago-Chile
- Edificio Citypark 1, Santiago-Chile
- Edificio Citypark 4, Santiago-Chile
- Edificio Citypark 6, Santiago-Chile
- Edificio Ingetasco Suecia, Santiago-Chile
- Edificio Ingetasco Bucarest, Santiago-Chile
- Edificio Eureka, Lima-Perú
- Edificio Orquideas, Lima-Perú
- Edificio San Isidro, Lima-Perú
- Edificio San Borja, Lima-Perú
- Edificio Torre Panamá, Lima-Perú
- Edificio Real 2, Lima-Perú
- Edificio Rivera y Navarrete, , Lima-Perú
- Edificio San Cayetano 2, Bogotá, Colombia
- Edificio San Cayetano 3, Bogotá, Colombia
- Edificio BMW, Bogotá, Colombia
- Edificio Colpatria C84, Bogotá, Colombia

INDUSTRIA Y SERVICIOS

- Planta Kaufmann Concepción, Concepción-Chile
- Planta Honda, Santiago-Chile
- Planta Kaufmann Mercedes Center, Santiago-Chile
- Centro SENAME, Victoria - Chile

RESIDENCIALES

- Plaza Universitaria, Santiago-Chile
- Condominio Real Ibiza, Playa del Carmen–México
- Condominio Roces de Gijón, Gijón-España
- Valle San Francisco, Santiago-Chile
- Rafael Sancio, Santiago-Chile
- Torre Woermann, Gran Canaria-España
- Barrio Inglés, Temuco-Santiago
- Tamarugo, Santiago-Chile
- Cerro Alvarado, Santiago-Chile
- Portezuelo, Santiago-Chile
- Tiziano, Santiago-Chile

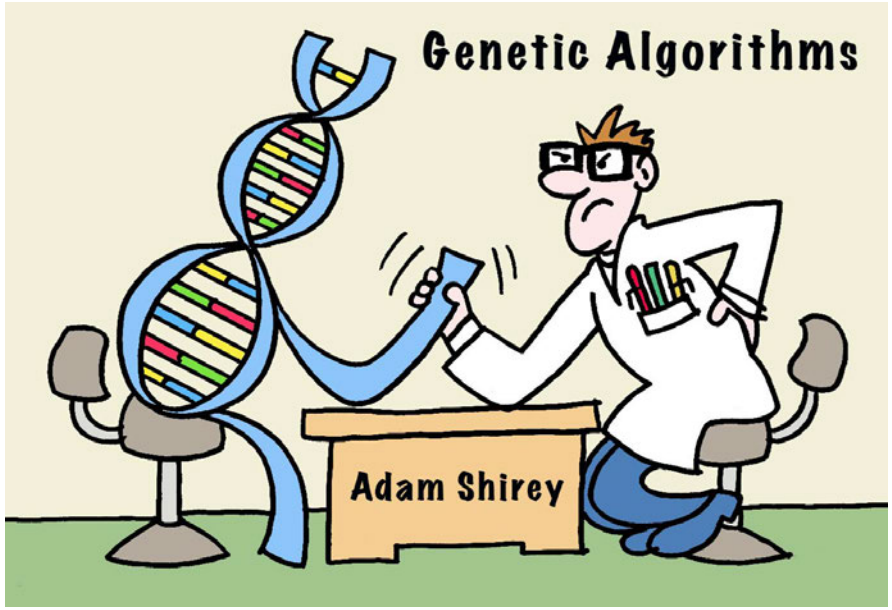
Agenda

- ✓ Síntesis de prácticas actuales de evaluación ambiental de edificios

- ✓ **Innovación y futuras tendencias en optimización del performance ambiental y económico de:**
  - ❑ **Edificios**
  - ❑ Barrios y Ciudades
  - ❑ Infraestructura

FROM ARTIFICIAL INTELLIGENCE WE LEARNED TO USE…

EVOLUTIONARY OPTIMIZATION APPROACHES FOR ARCHITECTURAL DESIGN



HOW TO EVALUATE ALL DESIGN POSSIBILITIES?

11 Design Variables

- Wall insulation (5, 7.5, 10)
- Floor insulation (5)
- Roof insulation (10,15, 20)
- Lighting systems (T5, LED, Ph)
- Natural ventilation (0,1)

Table 2 Description of the simulated parametric variables

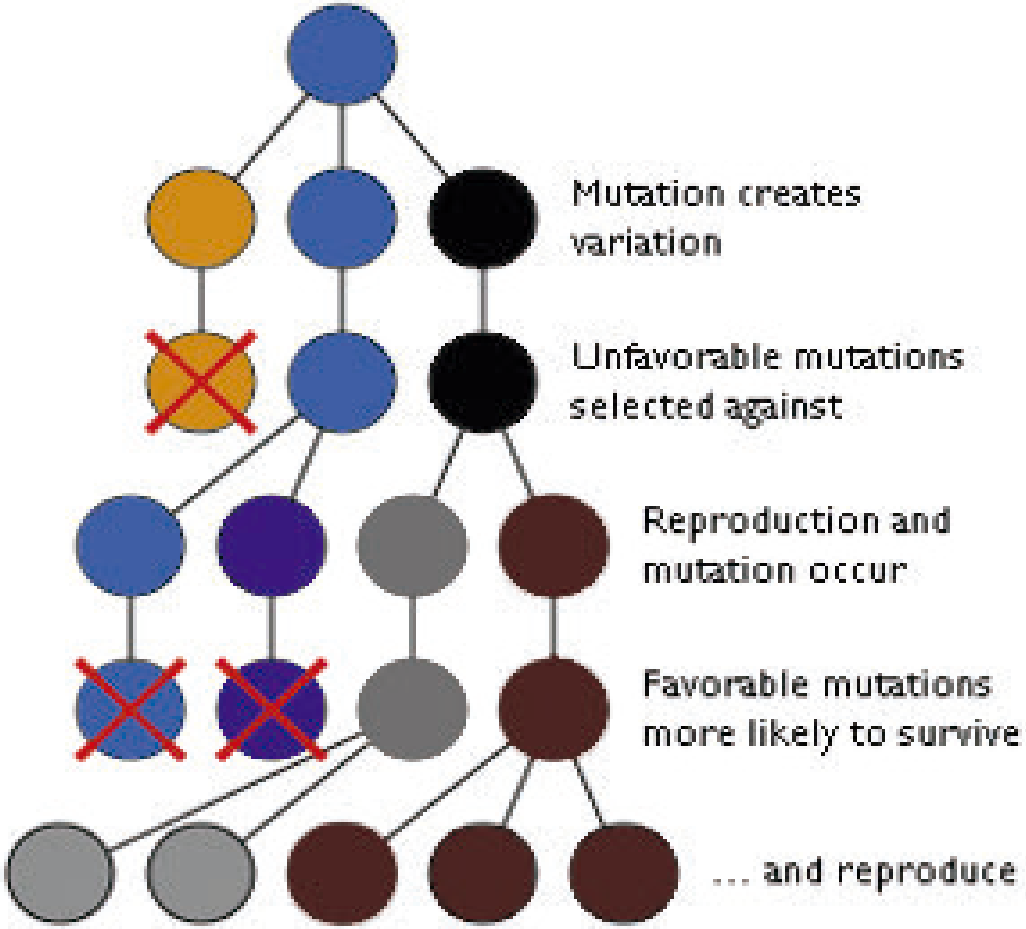
Variables tested	N°	Selected Parameters
Building Connection To The Ground	2	Standing on the ground plate or suspended
Wall Insulation Thicknesses	3	0.334 m, 0.384 m, 0.434 m
Floor Insulation Thicknesses	3	0.334 m, 0.384 m, 0.434 m
Roof Insulation Thicknesses	3	0.334 m, 0.384 m, 0.434 m
Main Window Overhang Depth	4	0 m, 0.55 m, 1.1 m, 1.65 m
Natural Ventilation Schedules (Natural Heat Exchanger Control)	4	Always on, always off, summer on, 9-17 on
Concrete Thermal Mass Thicknesses	3	0 m, 0.05 m, 0.1 m
Number Of Users (Daytime)	3	1, 2, 3 persons

11 Design Variables with **139,968 possible combinations**

simulation time > 10,000 hrs (+ 1year)

Source: Building Simulation 2013, Chamberry, France. IBPSA

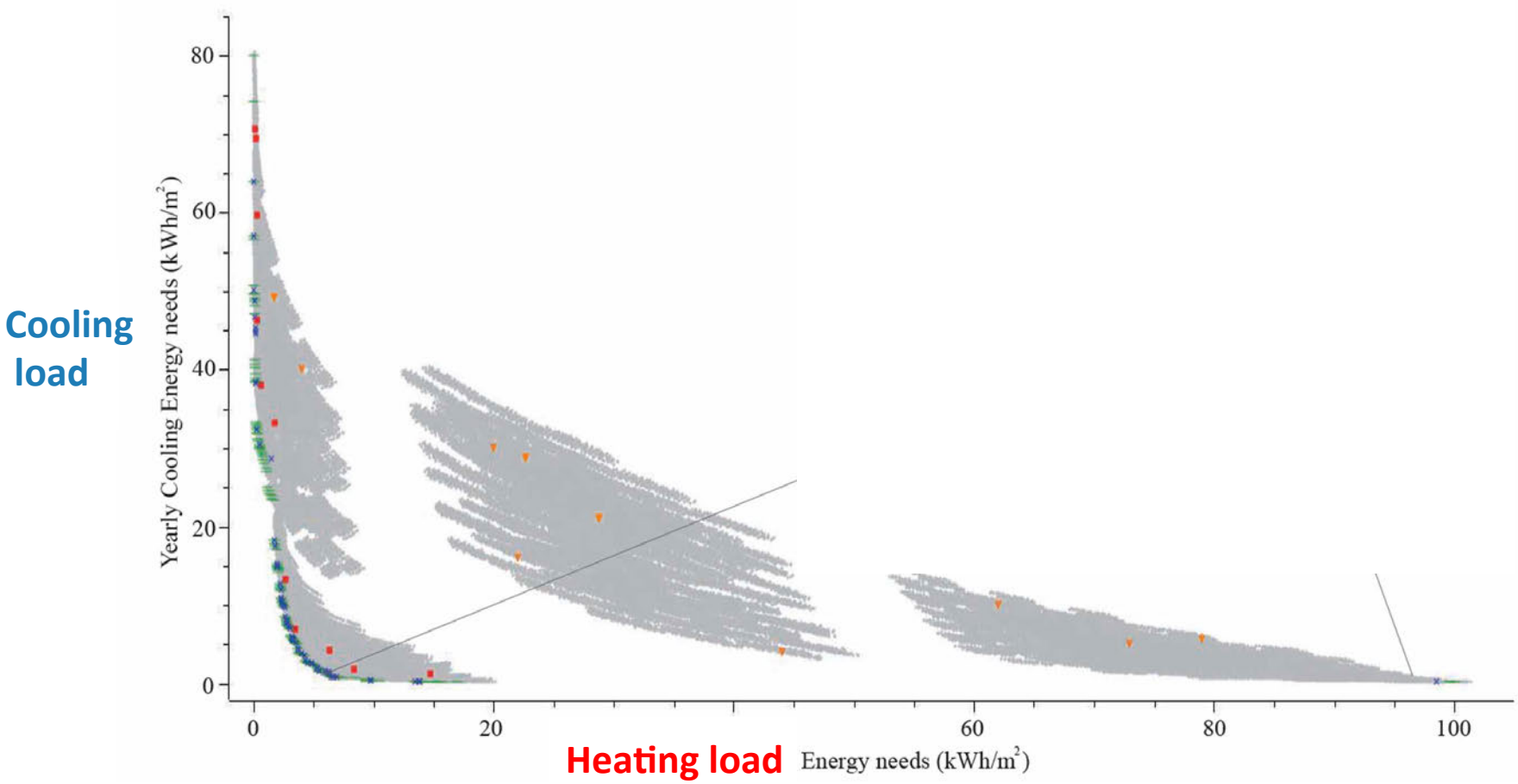
EVOLUTIONARY **OPTIMIZATION** FOR ARCHITECTURAL DESIGN



Source: IEEE. An Educational Genetic Algorithms Learning Tool

GENETIC ALGORITHM SIMULATION

Population of 10 with 135 generation for a **total of 1,350 simulations**
10 hours on dual core PC (3 on 10 core mini cluster)(jEplus+EA)



Source: Emmanuel Naboni. Comparison of Conventional, Parametric and evolutionary optimization approaches for the Architectural Design. Building Simulation 2013, Chambery, France. IBPSA

Building Lifecycle Profitability

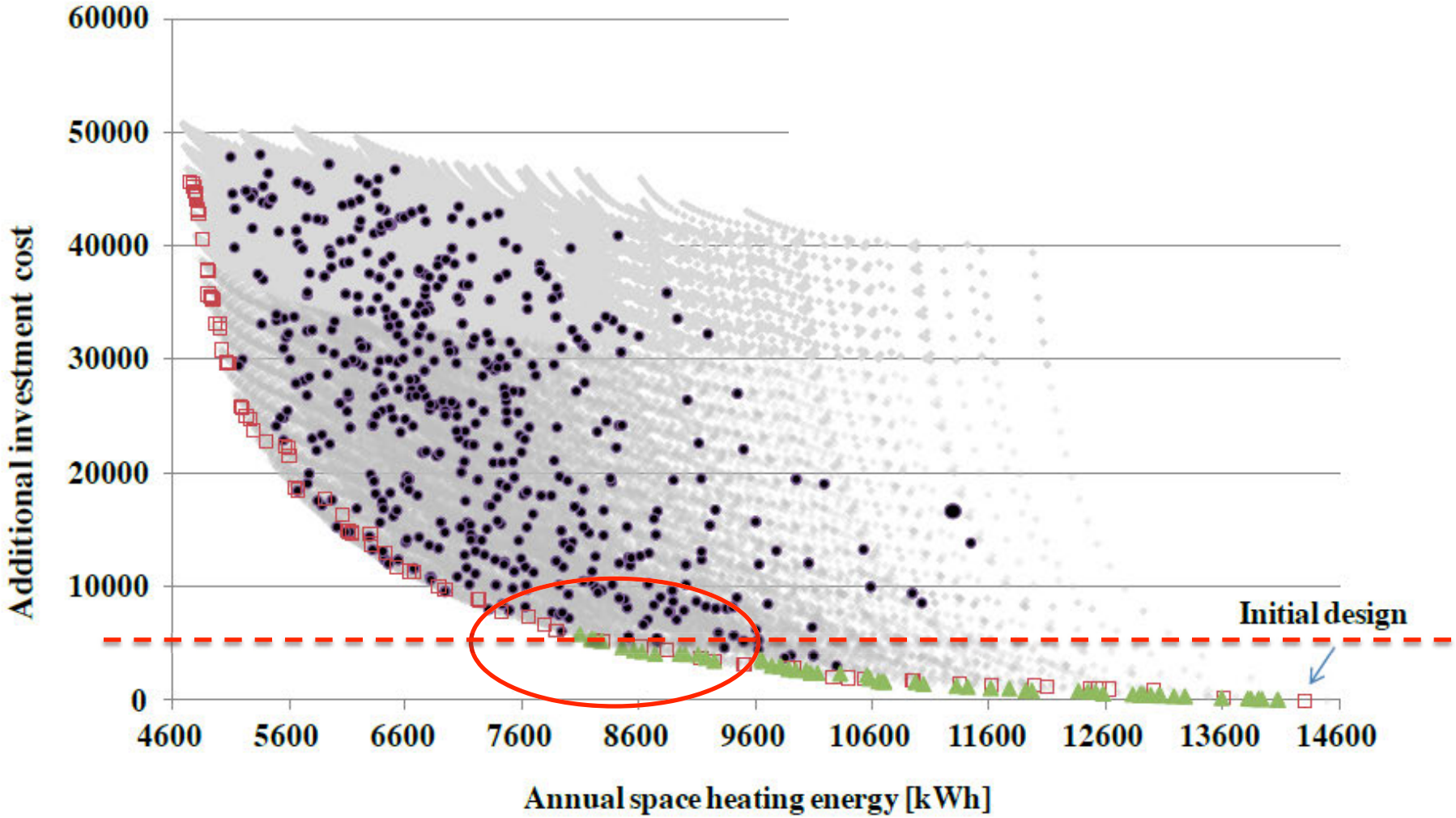
With similar insight, now you can calibrate your investments in building performance to drive optimal lifecycle profitability.

We call that Moneyball for Building Owners.

We Make Buildings More Profitable.

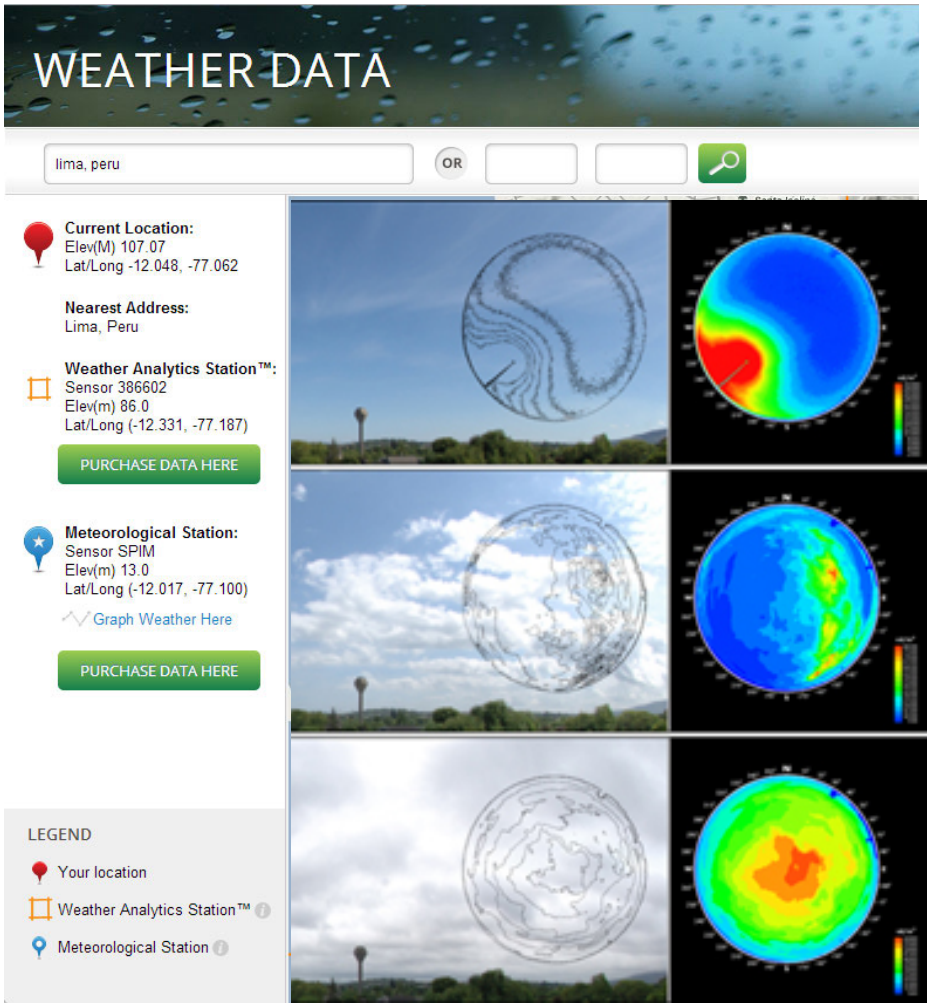
ECON

CONFIDENTIAL
COPYRIGHT ©2013 ECON GROUP

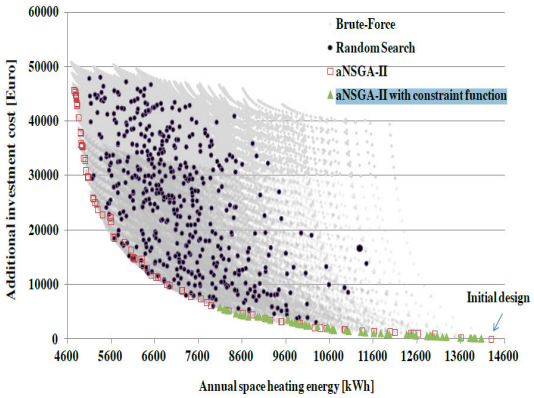


Source: MOBO, VTT Research Center of Finland, Espoo, Finland

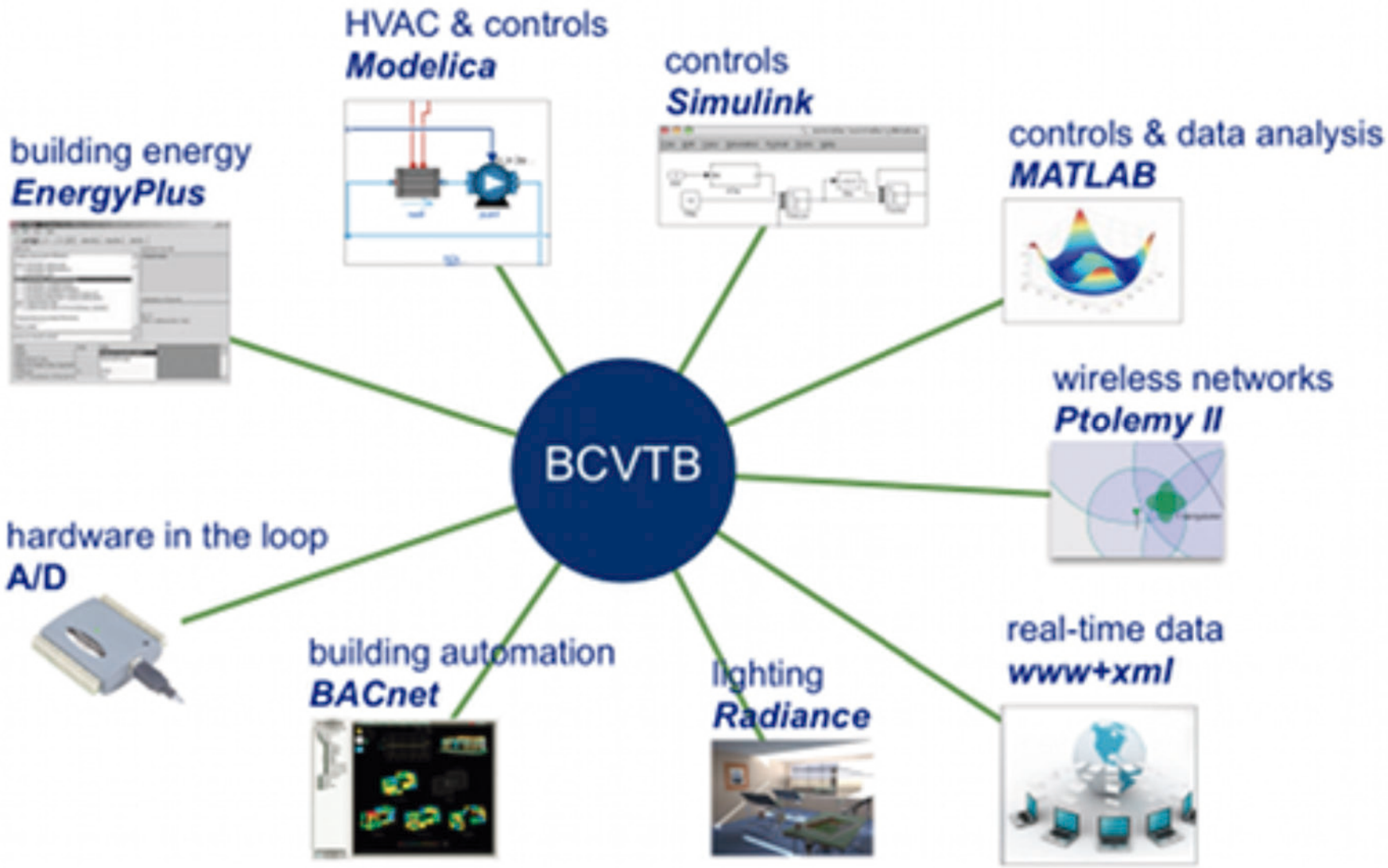
CONFIDENTIAL
COPYRIGHT ©2013 ECON GROUP



+



CONFIDENTIAL
COPYRIGHT ©2013 ECON GROUP



Source: lbnl.gov

CONFIDENTIAL
COPYRIGHT ©2013 ECON GROUP

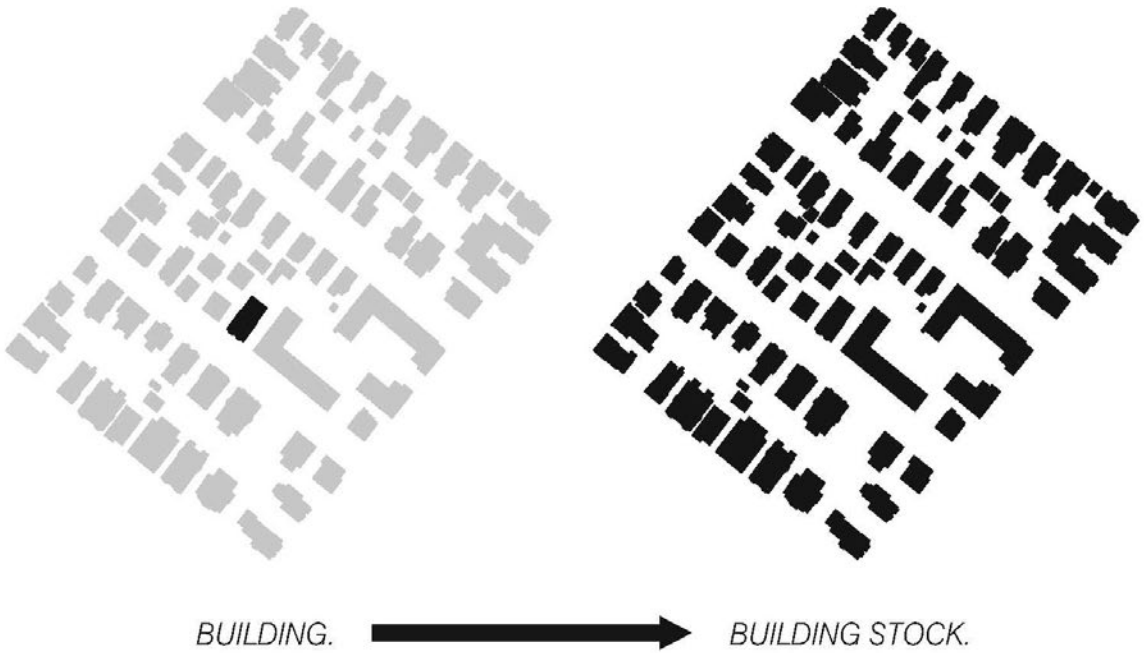
Agenda

- ✓ Síntesis de prácticas actuales de evaluación ambiental de edificios

- ✓ **Innovación y futuras tendencias en optimización del performance ambiental y económico de:**
  - ❑ Edificios
  - ❑ **Barrios y Ciudades**
  - ❑ Infraestructura

URBAN ENERGY LIFE CYCLE

Energy impacts need to be analyzed
at the scale of urban fabrics

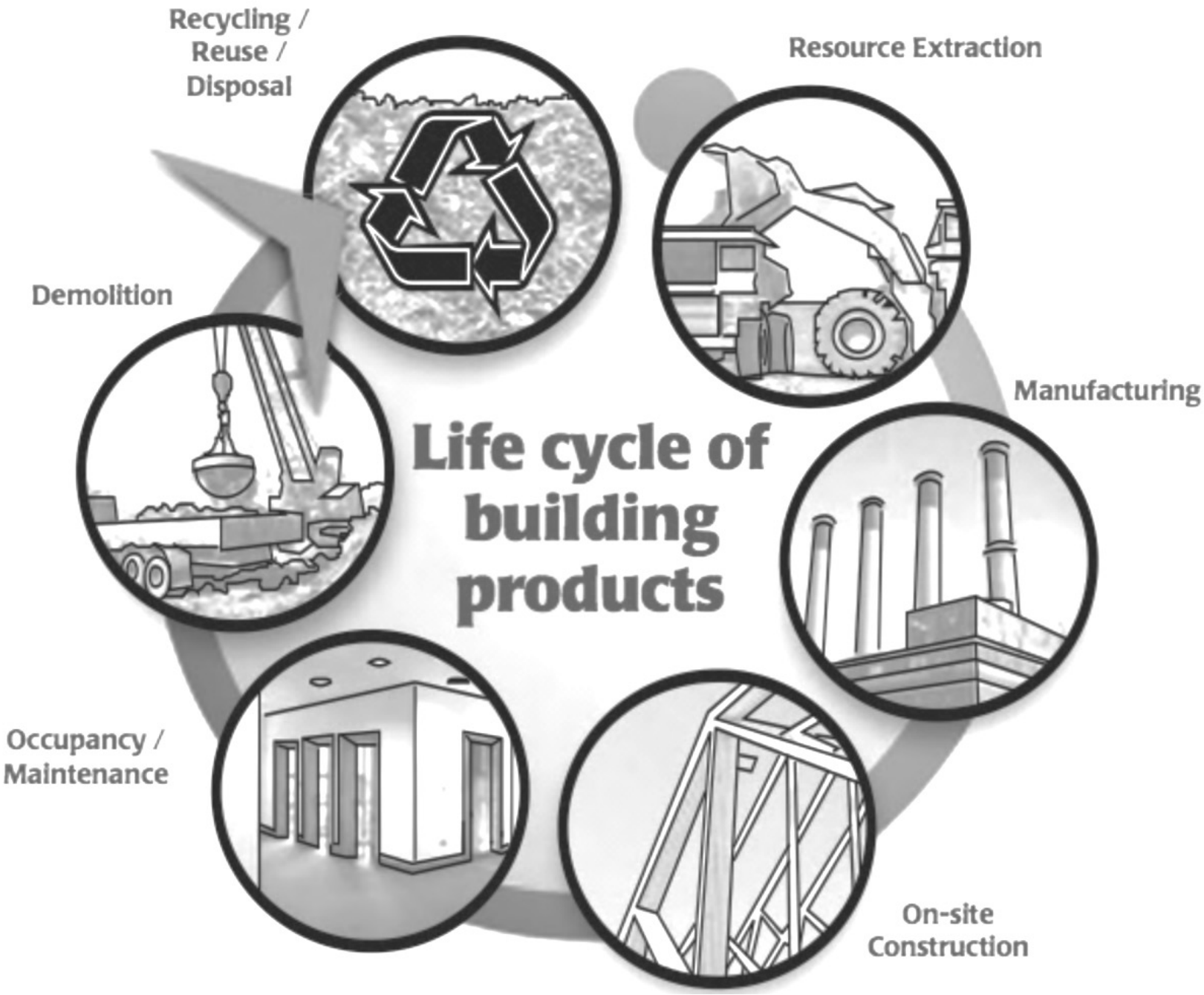


Harvard University

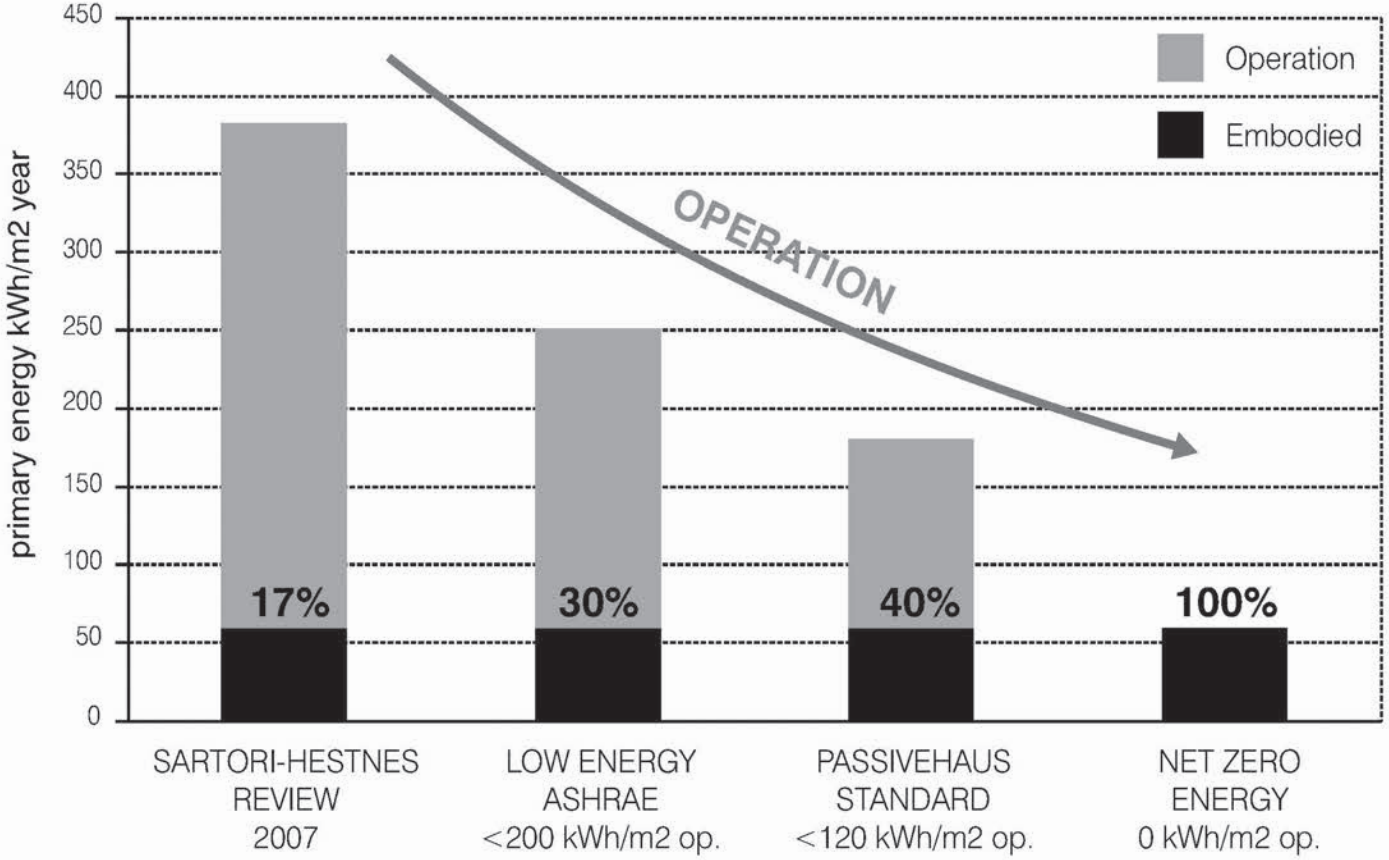
Carlos Cerezo Davila, ccerezod@mit.edu
Christoph Reinhart, tito_@mit.edu
MIT Sustainable Design Lab, Cambridge, MA

Massachusetts Institute of Tech.
Department of Architecture
Building Technology Program
Sustainable Design Lab

Source: Carlos Cerezo, Harvard University


Life cycle of building products
Recycling / Reuse / Disposal
Resource Extraction
Manufacturing
On-site Construction
Occupancy / Maintenance
Demolition

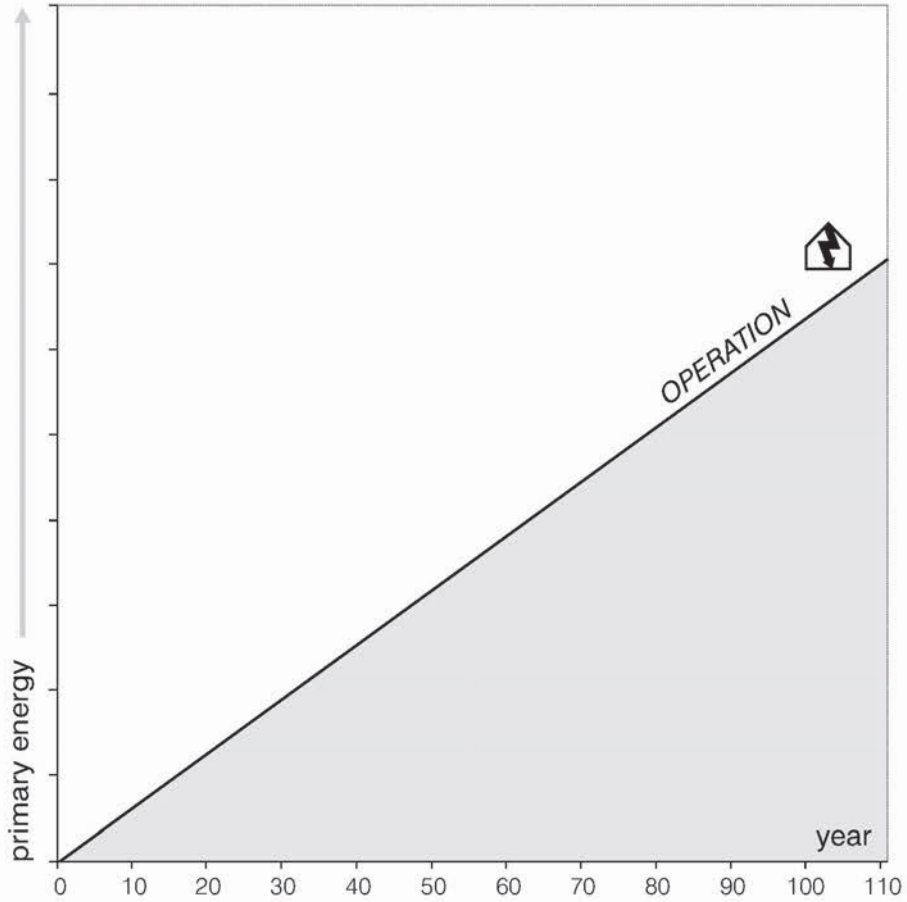
Embodied energy significance increases with the growth of energy efficiency codes, standards and technology.



Increasing importance of embodied energy in low energy buildings lifecycle.

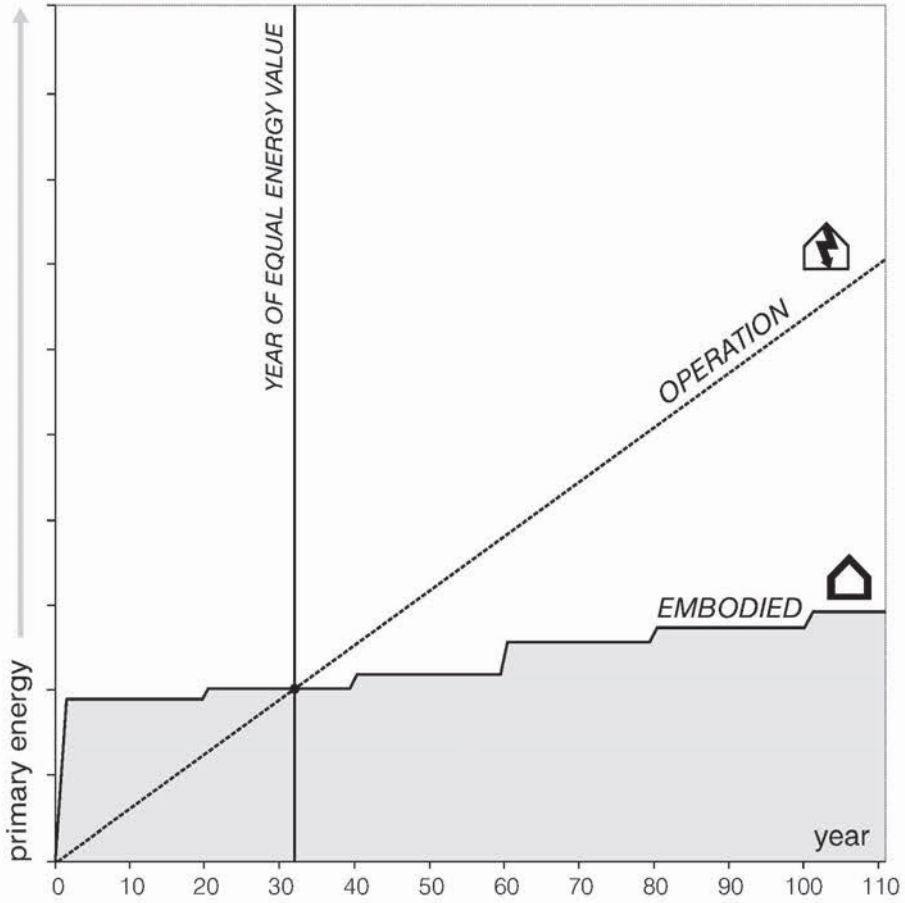
Source: Adapted from Sartori I. Hestnes A.G. (2007). 'Energy use in the life cycle of conventional and low-energy buildings: A review', Energy and buildings, 39, Elsevier

Designers and managers of cities are required to make predictions of the energy consequences of buildings.



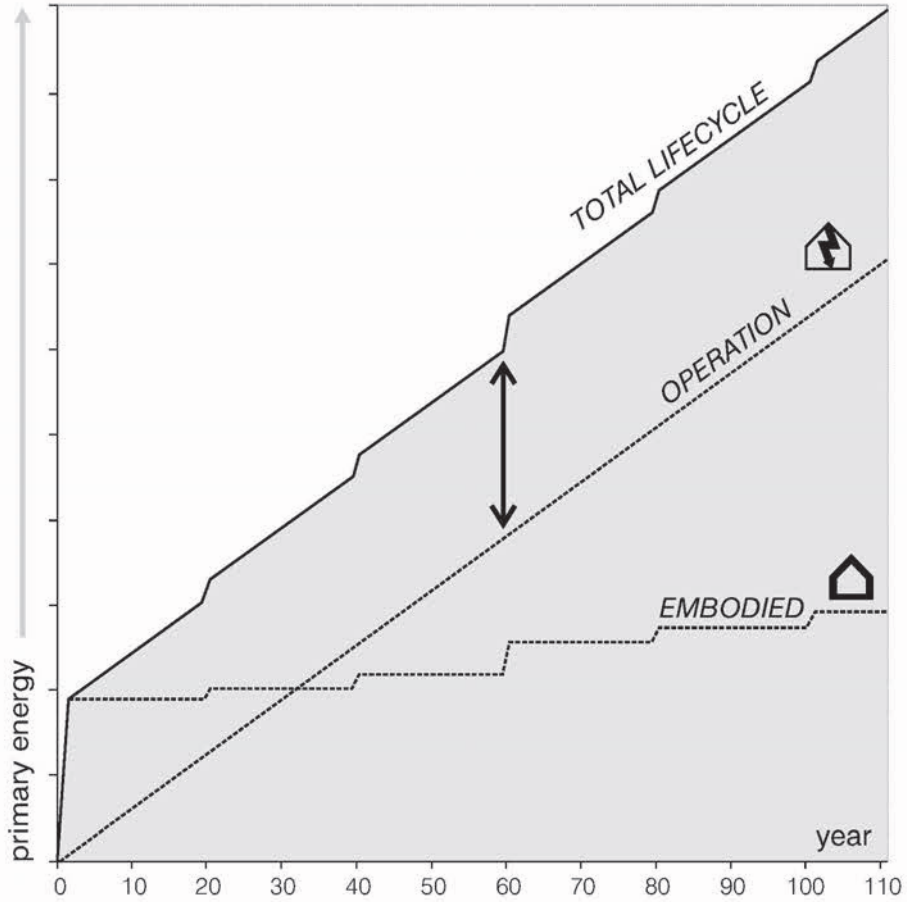
Embodied, operation and total energy functions in time.

Life cycle Embodied Energy represents material impacts, with a different long term profile from operation.



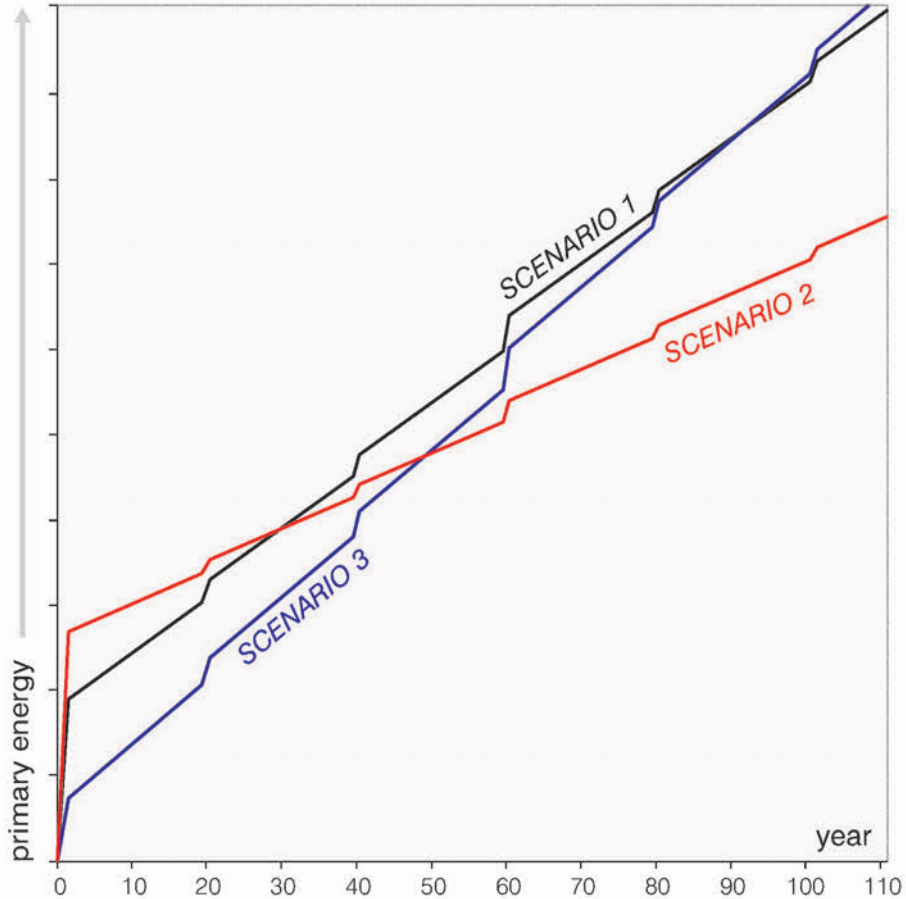
Embodied, operation and total energy functions in time.

Total cumulative energy profiles of cities
need to be compared to address long term scenarios.



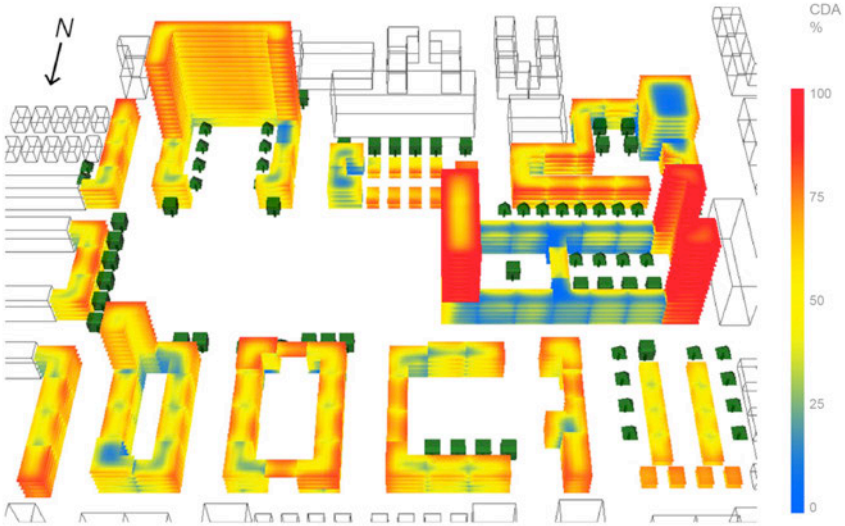
Embodied, operation and total energy functions in time.

Total cumulative energy profiles of cities
need to be compared to address long term scenarios.

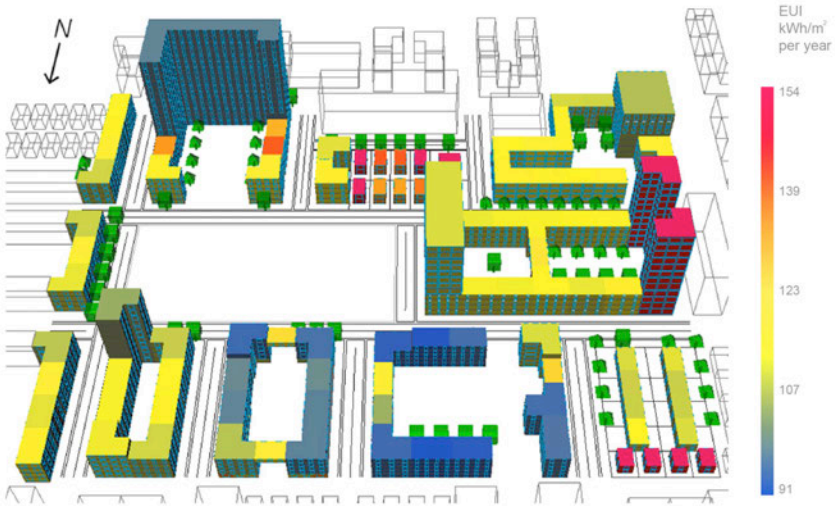


Embodied, operation and total energy functions in time.

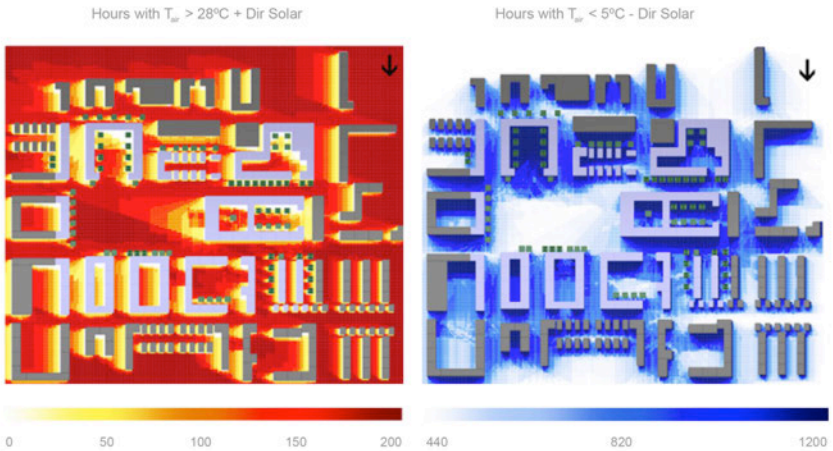
Source: Carlos Cerezo, Harvard University



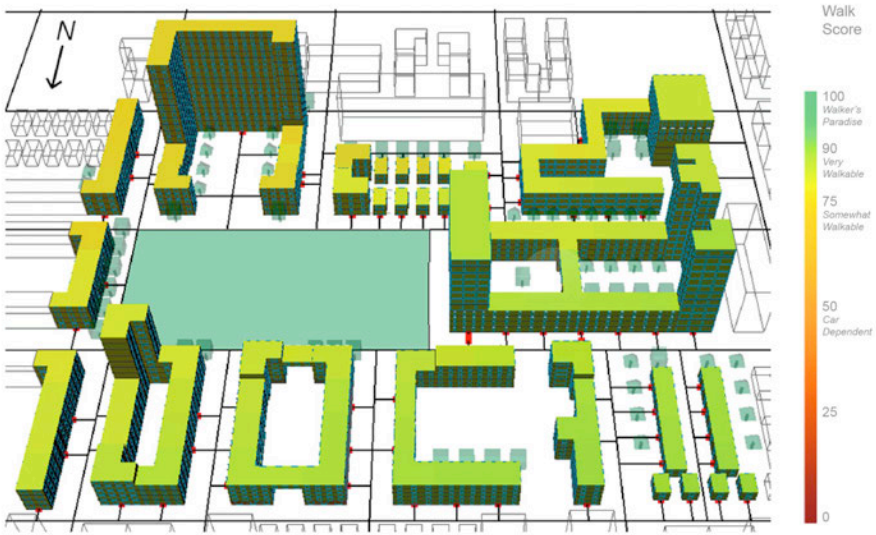
Daylight



Operational Energy



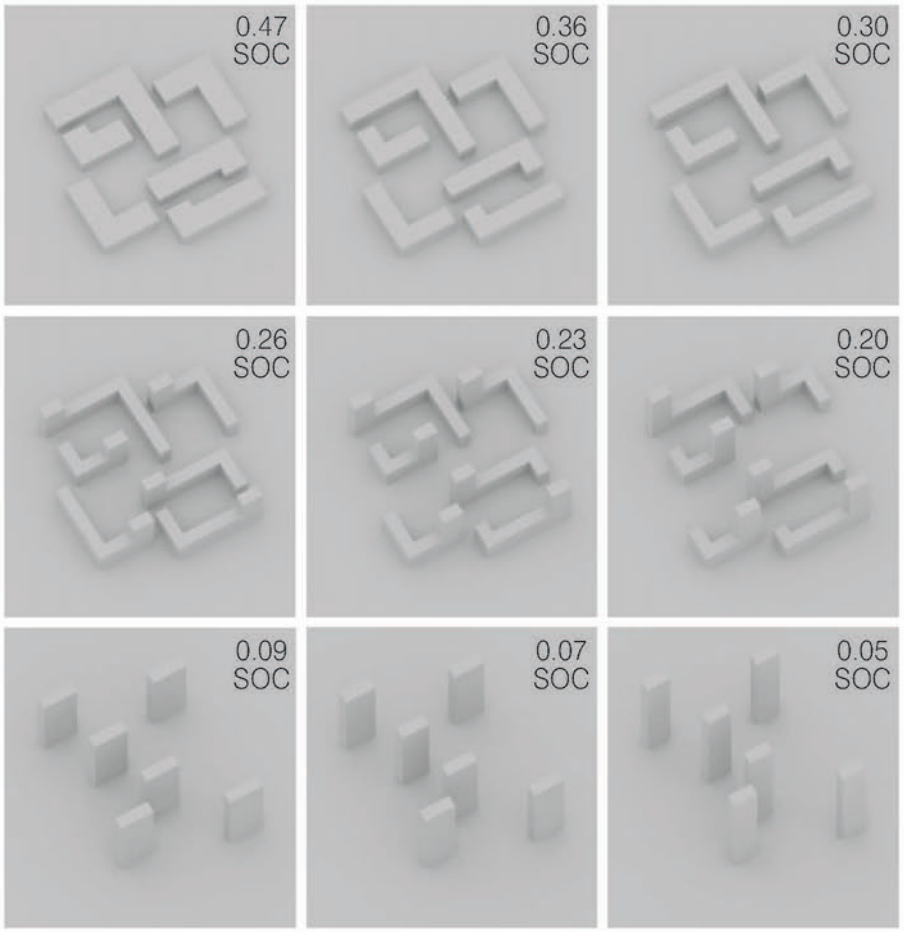
Outdoor Comfort



Mobility

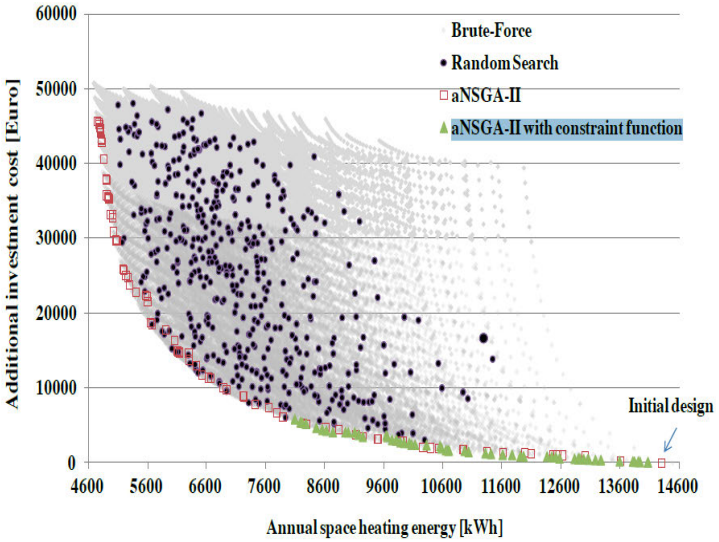
Source: Tarek Rahka, MIT

Parametric and Genetic Optimizations of Urban Form Studies



Urban residential fabric parametric geometry model.

+



Agenda

- ✓ Síntesis de prácticas actuales de evaluación ambiental de edificios

- ✓ **Innovación y futuras tendencias en optimización del performance ambiental y económico de:**
  - ❑ Edificios
  - ❑ Barrios y Ciudades
  - ❑ **Infraestructura**

THE IMPORTANCE OF INFRASTRUCTURE

Infrastructure provides:

- A basis for public health
- A quality of life worth living
- Economic viability

Infrastructure is **facing challenges**:

- Aging Infrastructure
- **Population Growth**
- **Diminished Resources/high operating cost**
- **Climate Change**

It is no longer enough that infrastructure **work**, that it be constructed **on time** and **within budget**, or even that it last. **It now must be *sustainable.***

© 2015 ISI, Inc., all rights reserved.

THE ENVISION® RATING SYSTEM

Institute for Sustainable Infrastructure

ZOFNASS PROGRAM FOR SUSTAINABLE INFRASTRUCTURE

APWA

ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

EA BUILDINGS

WHAT IS ENVISION?

WHAT MAKES ENVISION UNIQUE?

ENVISION'S MISSION

To help infrastructure **owners** make more **informed decisions about the sustainability** of their infrastructure projects

Envision® is not a decision making tool…
It is a **decision making guide**

- Envision applies to all civil infrastructure
- Envision applies to all project phases
- Is designed to keep pace with a changing concept of sustainability

WHAT TYPES OF INFRASTRUCTURE CAN ENVISION™ RATE?

ENERGY

Geothermal
Hydroelectric
Nuclear
Coal
Natural Gas
Oil/Refinery
Wind
Solar
Biomass

WATER

Potable water distribution
Capture/Storage
Water Reuse
Storm Water
Management
Flood Control

WASTE

Solid waste
Recycling
Hazardous Waste
Collection & Transfer

TRANSPORT

Airports
Roads
Highways
Bikes
Pedestrians
Railways
Public Transit
Ports
Waterways

LANDSCAPE

Public Realm
Parks
Ecosystem Services

60 CREDITS IN 5 CATEGORIES

QUALITY OF LIFE
13 CREDITS

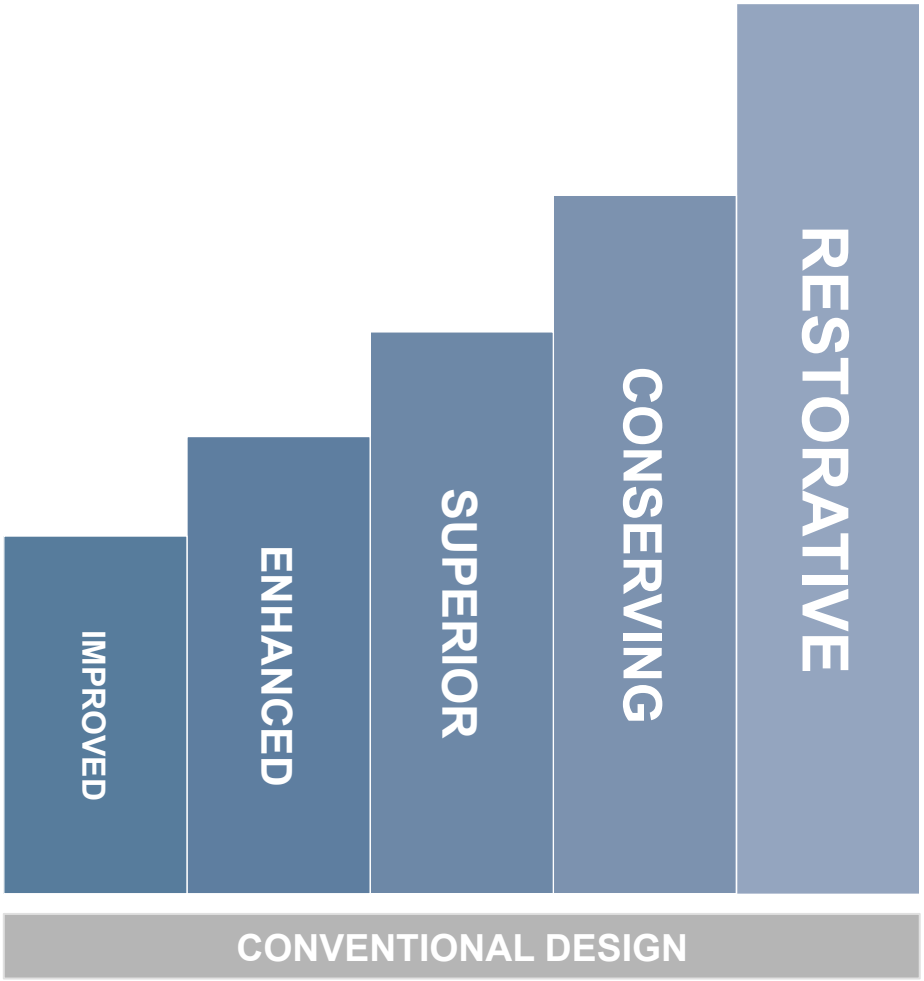
LEADERSHIP
10 CREDITS

RESOURCE ALLOCATION
14 CREDITS

NATURAL WORLD
15 CREDITS

CLIMATE AND RISK
8 CREDITS

5 LEVELS OF ACHIEVEMENT



QUALITY OF LIFE
13 Credits

1 PURPOSE
QL1.1 Improve Community Quality of Life
QL1.2 Stimulate Sustainable Growth & Development
QL1.3 Develop Local Skills & Capabilities

2 WELLBEING
QL2.1 Enhance Public Health & Safety
QL2.2 Minimize Noise and Vibration
QL2.3 Minimize Light Pollution
QL2.4 Improve Community Mobility & Access
QL2.5 Encourage Alternative Modes of Transportation
QL2.6 Improve Accessibility, Safety, & Wayfinding

3 COMMUNITY
QL3.1 Preserve Historic & Cultural Resources
QL3.2 Preserve Views & Local Character
QL3.3 Enhance Public Space

QL0.0 Innovate or Exceed Credit Requirements

LEADERSHIP
10 Credits

1 COLLABORATION
LD1.1 Provide Effective Leadership & Commitment
LD1.2 Establish A Sustainability Management System
LD1.3 Foster Collaboration & Teamwork
LD1.4 Provide for Stakeholder Involvement

2 MANAGEMENT
LD2.1 Pursue By-Product Synergy Opportunities
LD2.2 Improve Infrastructure Integration

3 PLANNING
LD3.1 Plan For Long-Term Monitoring & Maintenance
LD3.2 Address Conflicting Regulations & Policies
LD3.3 Extend Useful Life

LD0.0 Innovate or Exceed Credit Requirements

RESOURCE ALLOCATION
14 Credits

1 MATERIALS
RA1.1 Reduce Net Embodied Energy
RA1.2 Support Sustainable Procurement Practices
RA1.3 Use Recycled Materials
RA1.4 Use Regional Materials
RA1.5 Divert Waste From Landfills
RA1.6 Reduce Excavated Materials Taken Off Site
RA1.7 Provide For Deconstruction & Recycling

2 ENERGY
RA2.1 Reduce Energy Consumption
RA2.2 Use Renewable Energy
RA2.3 Commission & Monitor Energy Systems

3 WATER
RA3.1 Protect Fresh Water Availability
RA3.2 Reduce Potable Water Consumption
RA3.3 Monitor Water Systems

RA0.0 Innovate or Exceed Credit Requirements

NATURAL WORLD
15 Credits

1 SITING
NW1.1 Preserve Prime Habitat
NW1.2 Protect Wetlands & Surface Water
NW1.3 Preserve Prime Farmland
NW1.4 Avoid Adverse Geology
NW1.5 Preserve Floodplain Functions
NW1.6 Avoid Unsuitable Development on Steep Slopes
NW1.7 Preserve Greenfields

2 LAND+WATER
NW2.1 Manage Stormwater
NW2.2 Reduce Pesticide & Fertilizer Impacts
NW2.3 Prevent Surface & Groundwater Contamination

3 BIODIVERSITY
NW3.1 Preserve Species Biodiversity
NW3.2 Control Invasive Species
NW3.3 Restore Disturbed Soils
NW3.4 Maintain Wetland & Surface Water Functions

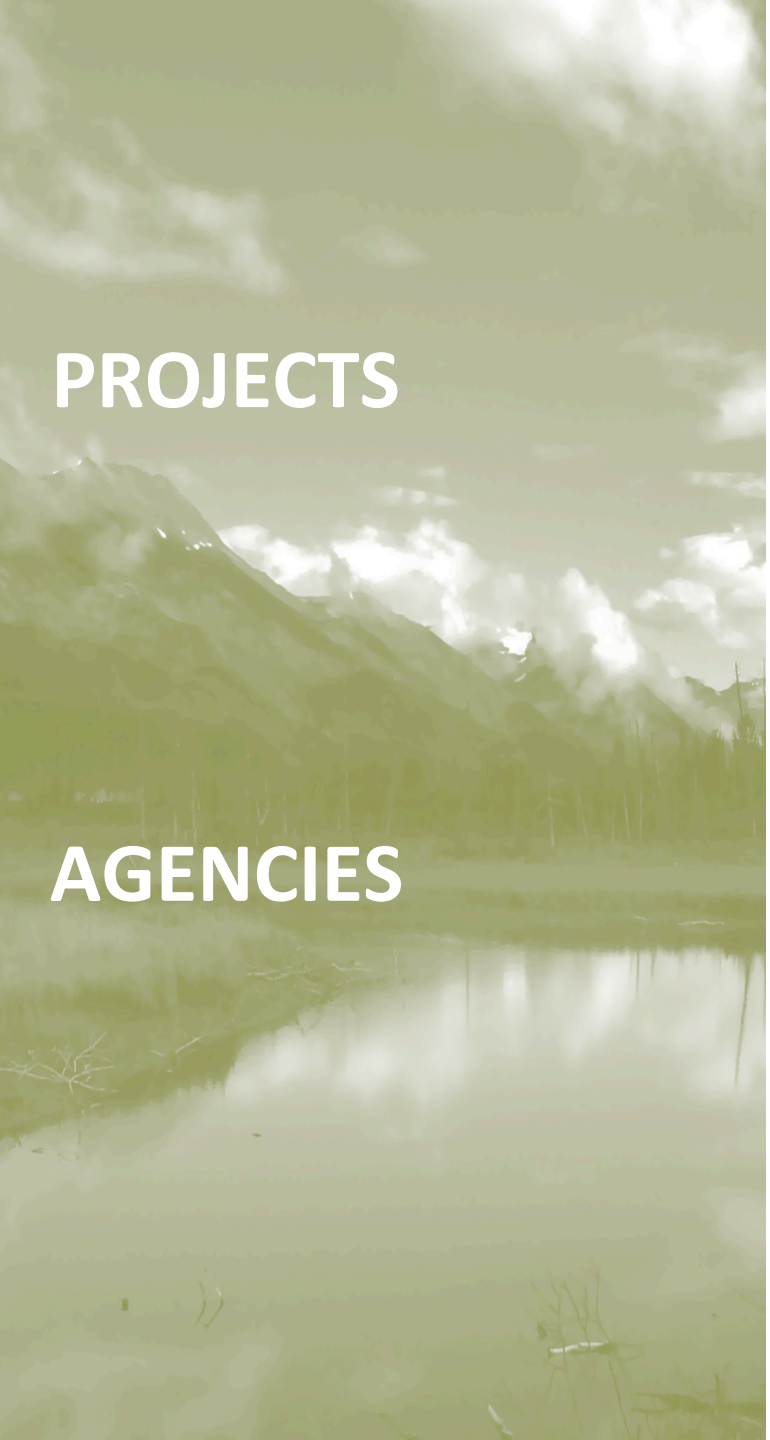
NW0.0 Innovate or Exceed Credit Requirements

CLIMATE AND RISK
8 Credits

1 EMISSIONS
CR1.1 Reduce Greenhouse Gas Emissions
CR1.2 Reduce Air Pollutant Emissions

2 RESILIENCE
CR2.1 Assess Climate Threat
CR2.2 Avoid Traps & Vulnerabilities
CR2.3 Prepare For Long-Term Adaptability
CR2.4 Prepare For Short-Term Hazards
CR2.5 Manage Heat Island Effects

CR0.0 Innovate or Exceed Credit Requirement



ENVISION USAGE

PROJECTS

AGENCIES

- Los Angeles County DPW
- NYC Dept. of Environmental Protection
- NYC Dept. of Design and Construction
- Port of Long Beach
- CA Dept. of Water Resources
- MassDOT, DelDOT, KCMO, Edina (MN)

© 2015 ISI, Inc., all rights reserved.

South Los Angeles Wetland Park
Envision Platinum

Los Angeles, California

Institute for Sustainable Infrastructure

ENVISION™

PLATINUM

Tarrant Regional Water District Pipeline
Envision Silver

North Central, Texas

Institute for Sustainable Infrastructure

ENVISION™

SILVER

Grand Bend Area Wastewater Treatment Facility
Envision Platinum

Grand Bend, Ontario

Institute for Sustainable Infrastructure
ENVISION™
PLATINUM

USING ENVISION

- **Improve project phases**
  - **Planning**
  - **Design**
  - Construction
  - Operations and Maintenance

- Incorporate into
  - Policies and standards
  - Public outreach
  - Grant funding
  - Design competitions

© 2015 ISI, Inc., all rights reserved.

Acknowledgement

HARVARD + MIT Sustainable Design Lab

Harvard University

Massachusetts Institute of Tech.
Department of Architecture
Building Technology Program
Sustainable Design Lab

EA BUILDINGS

ENVIRONMENTAL ANALYTICS FOR SMART INVESTMENTS

Gracias

diego.ibarra@ea-buildings.com

ASHRAE

U.S. GREEN BUILDING COUNCIL MEMBER

IBPSA

Institute for Sustainable Infrastructure