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An Approach to Develop a Green Building Database for Residential buildings

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Introduction
background

Buildings consume considerable amount of resources like energy, water and building materials during their constructing and operating, and may affect the local/global environment as well, e.g. producing greenhouse gases and affecting urban heat island. IEQ performance can affect occupant health, perception, comfort and working efficiency.

Buildings are expected to have **high performance** (energy efficiency, IAQ, thermal comfort…)

High-performance building standards

living lab

Syracuse CoE

High-performance building cases

Introduction
database for green buildings

Database Name	Institute	Scope
Building Performance Database (BPD)	LBNL	US
EnerGuide for Houses Database (EGHD)	Natural Resources Canada	Canada
Low Energy Building (LEB) Database	Technology Strategy Board of UK	UK
…	…	…

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Whole-building performance (measured and/or simulated)

There's no available green building database based on the **performance for building technologies**

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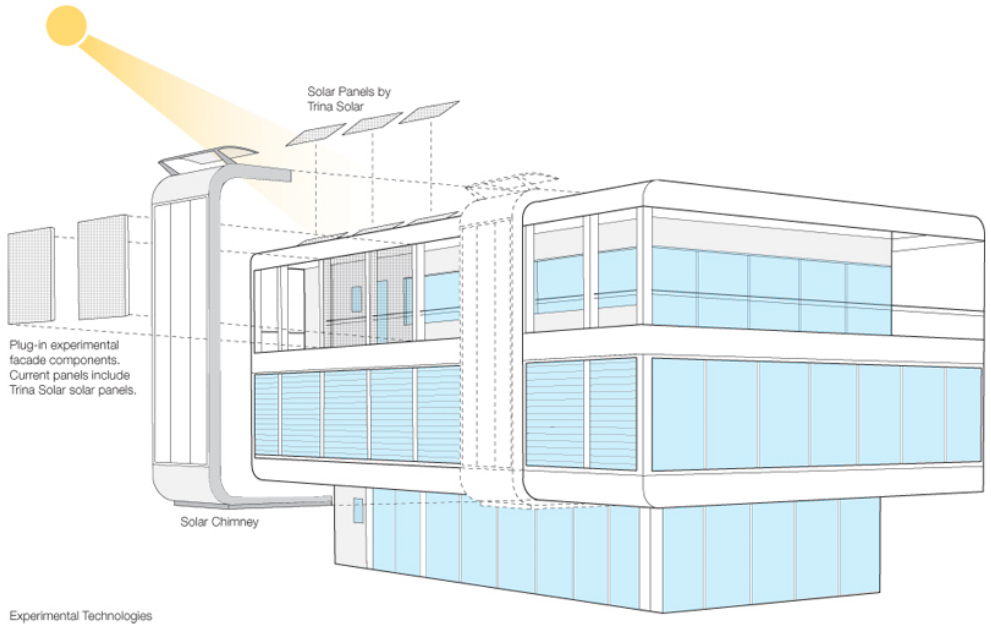
Module-based high-performance building design



Changzhou P+ Building

Introduction
module-based design

Database based on the performance for green building technologies

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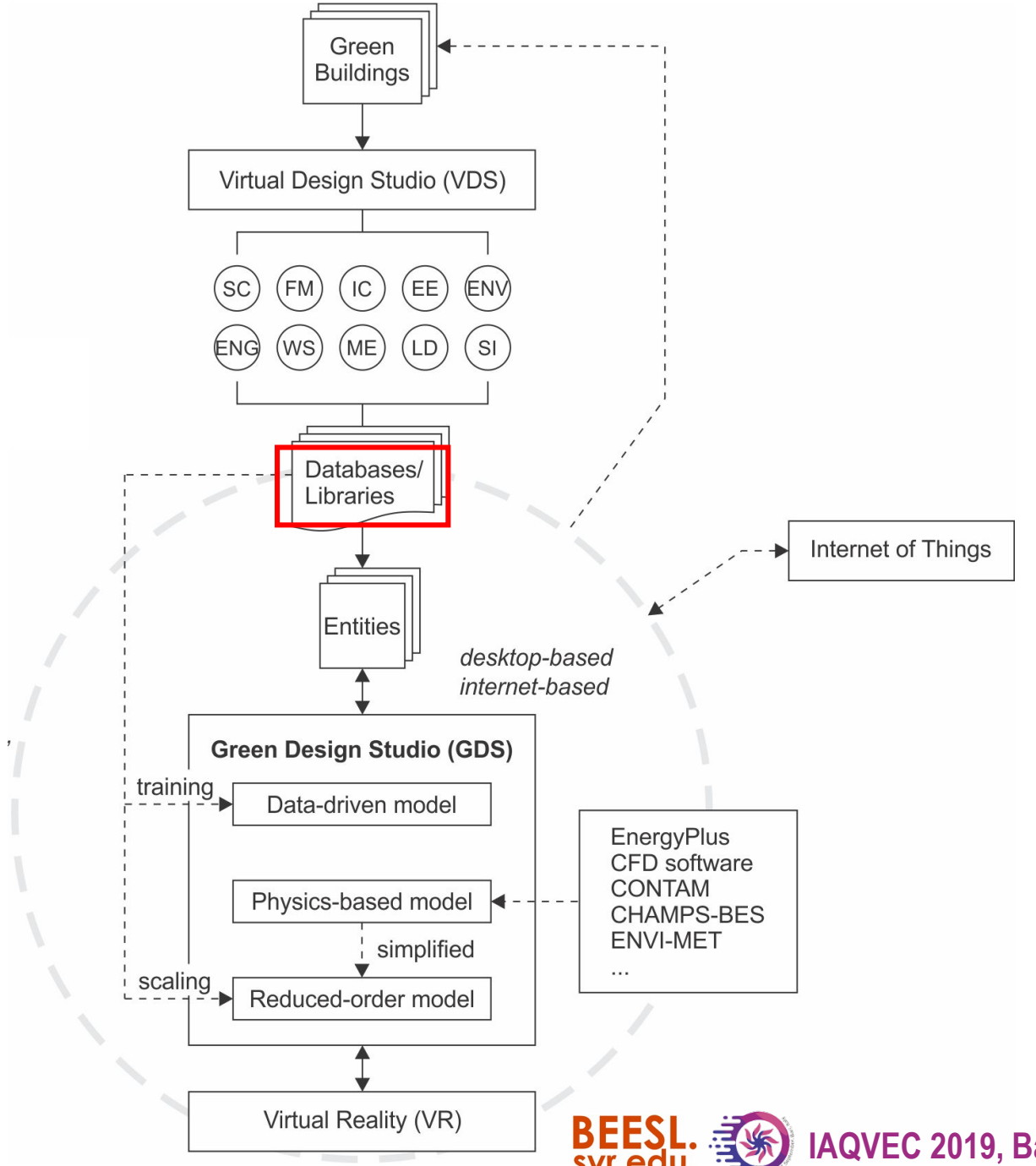
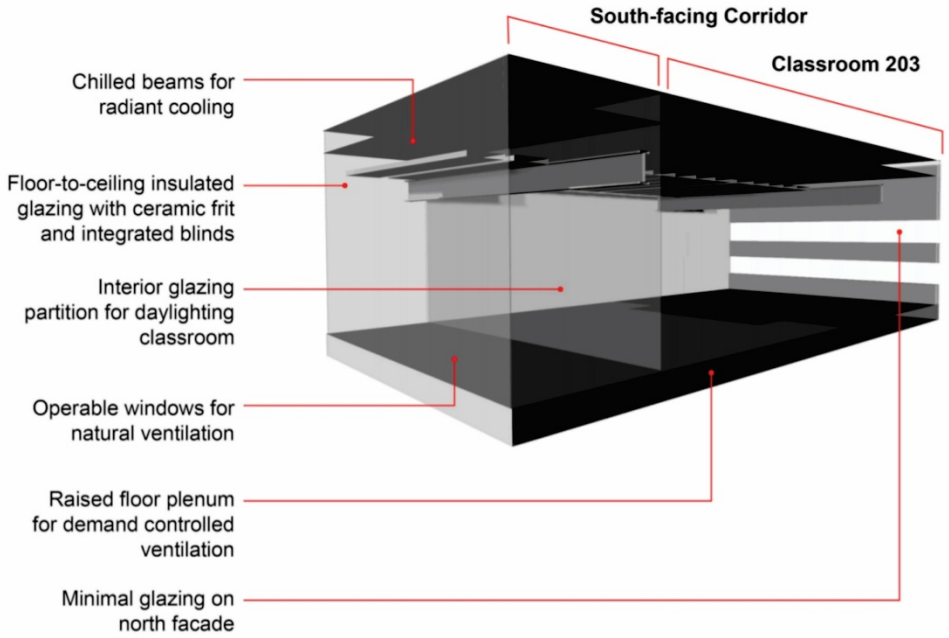
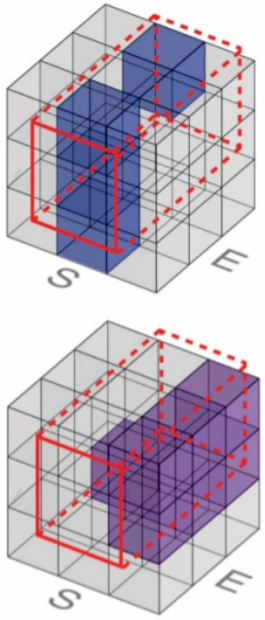
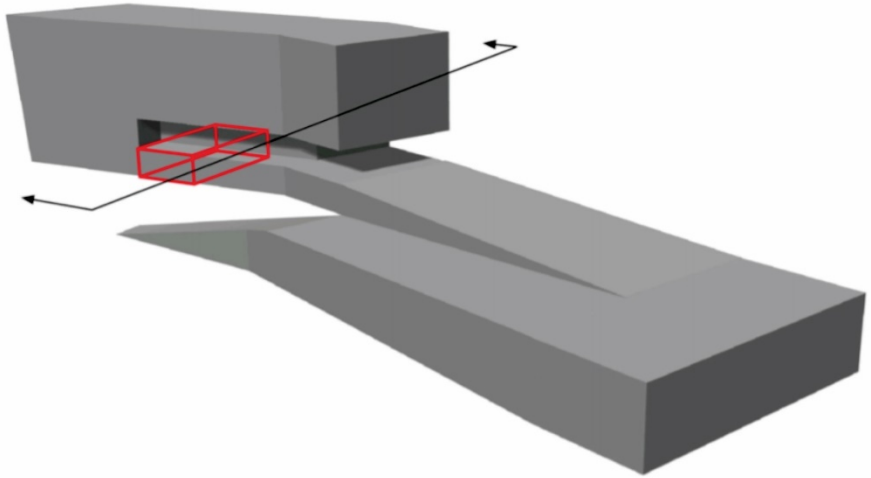
Module-based high-performance building design



Introduction
module-based design







Green Building Technologies ⇨ Green Building Entities ⇨ Green Building

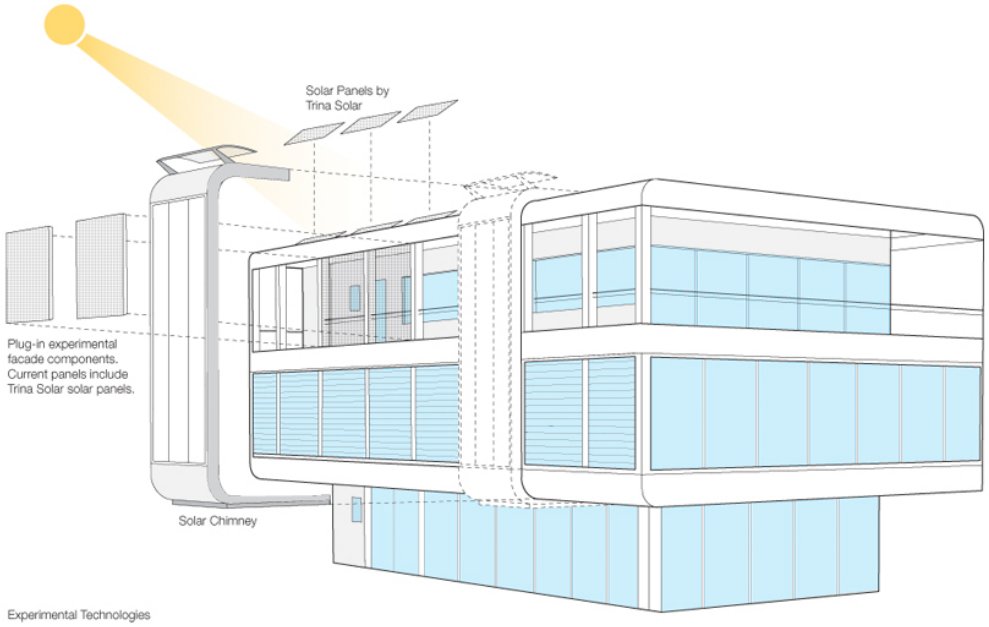
Green Building Technologies (GBT)
definition & data collection

Green building
Buildings that can elevate their performance against the *local reference buildings*

Green building technologies
Building-related technologies and design features which can improve the building performance

Local reference building
A building with typical building features and technologies in a local area/climate zone

Data collection
- Cases from existing green building databases
- Green building cases from literature
- Existing green buildings



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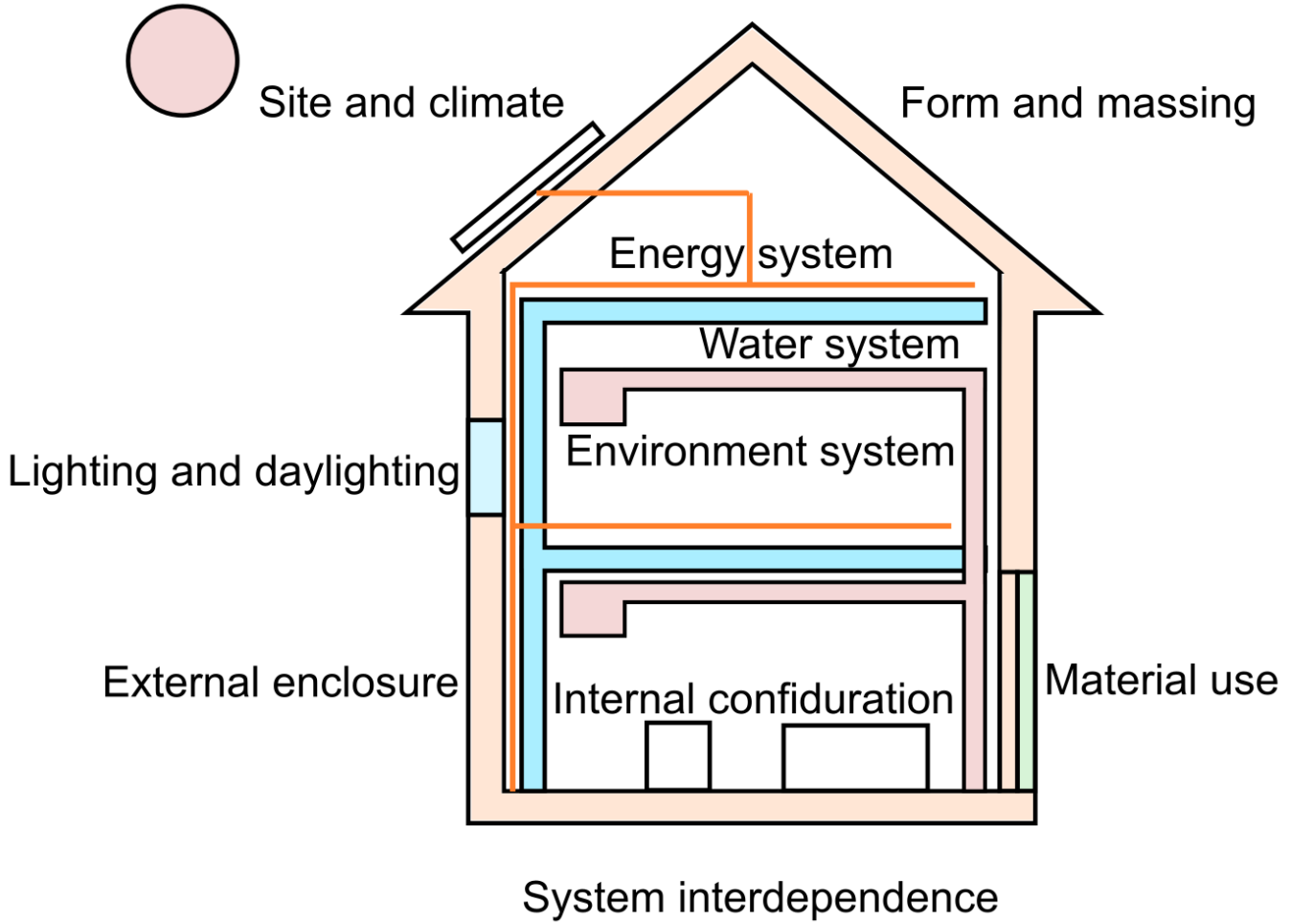
Green Building Technologies (GBT)
classification

Green Building Technologies related to …

1. Site & Climate (SC)
2. Form & Massing (FM)
3. Internal Configuration (IC)
4. External Enclosure (EE)
5. Environmental System (ENV)
6. Energy System (ENG)
7. Water System (WS)
8. Lighting & Daylighting (LD)
9. Material & Embodied Energy (ME)
10. System Interdependence (SI)



Green Building Technologies (GBT)
summary

GBT data collected from the residential buildings of Low Energy Building (LEB) database and literature.

GBTs were categorized to passive technologies, service systems and renewable energy generation technologies.

Category		GBT	Design factors									
			SC	FM	IC	EE	ENV	ENG	WS	ME	LD	SI
Passive technologies	Building envelope	Thermal insulation				✓				✓		
		Ventilated/double-skin walls/roofs/floors				✓						
		Passive solar walls	✓			✓						
		Energy-saving glazing technologies	✓			✓				✓	✓	
		Passive shading technologies	✓	✓							✓	
		Low infiltration				✓						
		Solar-reflective/cool roofs	✓			✓				✓		
		Green roofs	✓			✓						
		Evaporative roof cooling				✓						
	Passive heating, cooling & ventilation	Nighttime ventilation	✓				✓					
		Earth-to-air heat exchange	✓				✓					
		Natural ventilation	✓				✓					
		Solar chimney	✓			✓	✓					
	Thermal storage	Phase-change materials				✓				✓		
		Thermal mass		✓						✓		
Service systems	HVAC	Evaporative cooling					✓					
		Active thermal storage					✓					
		Heat recovery					✓					
		Radiant heating/cooling			✓		✓					
		VAV/VRF					✓					
	DWH	Solar water heater	✓						✓			
		Solar-assisted heat pump system	✓						✓			
		Combined cooling, heating and power							✓			✓
	Lighting	Daylight harvesting	✓								✓	
		LEDs									✓	
		Energy efficient lighting									✓	
		Active shading technologies	✓								✓	
	Appliances	Energy-efficient appliances										
Renewable energy generation	Solar energy	PV/building integrated PV	✓					✓				✓
		Hybrid PV-thermal	✓					✓				✓
	Wind energy	Wind turbine	✓					✓				
	Geothermal energy	Ground source heat pump	✓					✓				
	Bioenergy	Biomass heater						✓				

X. Cao, X. Dai, J. Liu, Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade, Energy Build. 128 (2016) 198–213.

Building Performance Assessment
performance aspects

Performance aspects of different green building standards

VDS	LEED (USGBC 2009)	ASHRAE 189.1 (ASHREA 2009)	BREEAM (UK) (BREEAM 2011)	DGNB (Germany) (DGNB 2008)	WBDG (PNNL 2005)
Site sustainability • Site selection • Mitigation of heat island effect • Reduction of light pollution	**Sustainable sites** • Site selection • Site development • Alternative transportation • Stormwater mgt. • Landscape design and reduction of heat island • Light pollution reduction	**Site sustainability** • Site selection • Mitigation of heat island effect • Reduction of light pollution • Site development	**Land use and ecology** • Site selection • Site ecology • Ecological impact • Enhancing site ecology • Long term impact on biodiversity **Transport** • Transport accessibility • Proximity to amenities	**Ecological quality** • Impacts on global and local environment **Quality of the process** • Quality of the planning • Quality of the construction activities	**Transportation** • Regular commute
Water efficiency • Site water use reduction • Building water use reduction • Water cons. measurement	**Water efficiency** • Water efficient landscaping • Innovative waste water technologies • Water use reduction	**Water use efficiency** • Site water use reduction • Building water use reduction • Water cons. measurement	**Water** • Water cons. • Water monitoring • Water leak prevention • Water efficient equipment	**Socio-cultural and functional quality** • Performance • Functionality **Technical quality** • Quality of the technical implementation	**Water** • Total building water use • Indoor potable water use • Outdoor water use • Total storm sewer output
Energy and atmosphere • Energy efficiency measures • On-site renewable energy systems • Energy cons. mgt.	**Energy and atmosphere** • Commissioning of the building energy systems • Refrigerant mgt. • Optimize energy performance • On-site renewable energy • Green power	**Energy efficiency** • On-site renewable energy systems • Energy cons. mgt. • Energy performance of building systems	**Energy** • Reduction of CO_2 emissions • Energy monitoring • External lighting • Low/zero carbon technologies • Energy efficient systems	**Socio-cultural and functional quality** • Performance • Functionality **Technical quality** • Quality of the technical implementation	**Energy** • Total building energy use • Source energy • Peak electricity demand
Indoor environmental quality • Indoor air quality • Thermal environmental condition • Acoustical control • Lighting	**Indoor environmental quality** • IAQ performance • Outdoor air monitoring • IAQ mgt. plan • Pollutant source control • Thermal comfort • Daylight & views	**Indoor environmental quality** • Indoor air quality • Thermal comfort • Acoustical control • Day lighting • Materials emissions	**Health & wellbeing** • Visual comfort • Indoor air quality • Thermal comfort • Water quality • Acoustic performance • Safety and security	**Socio-cultural and functional quality** • Performance • Health, comfort and user satisfaction • Functionality **Technical quality** • Quality of the technical implementation	**Occupant health and productivity** • Occupant turnover rate • Absenteeism • Building occupant satisfaction • Self-rated productivity
Materials and resources • Isolation pollutants in the soil • Waste mgt. • Materials use • Refrigerants use • Life-cycle assessment	**Materials and resources** • Storage & collection of recyclables • Construction waste management • Materials reuse • Regional materials • Rapidly renewable materials	**Buildings impact on the Atm. materials and resources** • Isolation pollutants in the soil • Construction waste mgt. • Materials manufacturing • Refrigerants use • Life cycle assessment	**Material** • Life cycle impacts • Sourcing of materials • Insulation • Designing for robustness **Waste** • Construction waste management • Recycled aggregates **Pollution** • Refrigerants • NO_x emissions • Surf. water runoff • Light pollution • Noise attenuation	**Ecological quality** • Impacts on global and local environment • Utilization of resources and waste arising **Economical quality** • Life cycle costs	**Waste generation** • Solid sanitary waste • Hazardous waste • Recycled materials

Performance aspects for GBT database → measured, simulated (currently used)

Site
- -> urban heat island effect
- -> urban ventilation performance

Energy efficiency
- -> energy consumption
- -> renewable energy use

Water efficiency
- -> water consumption

IEQ
- -> thermal comfort
- -> IAQ
  - -> ventilation rate
  - -> pollutant level
- -> lighting
- -> acoustic

Material and resource
- -> material use
- -> waste management
- -> life-cycle assessment

Building Performance Assessment
assessment approach

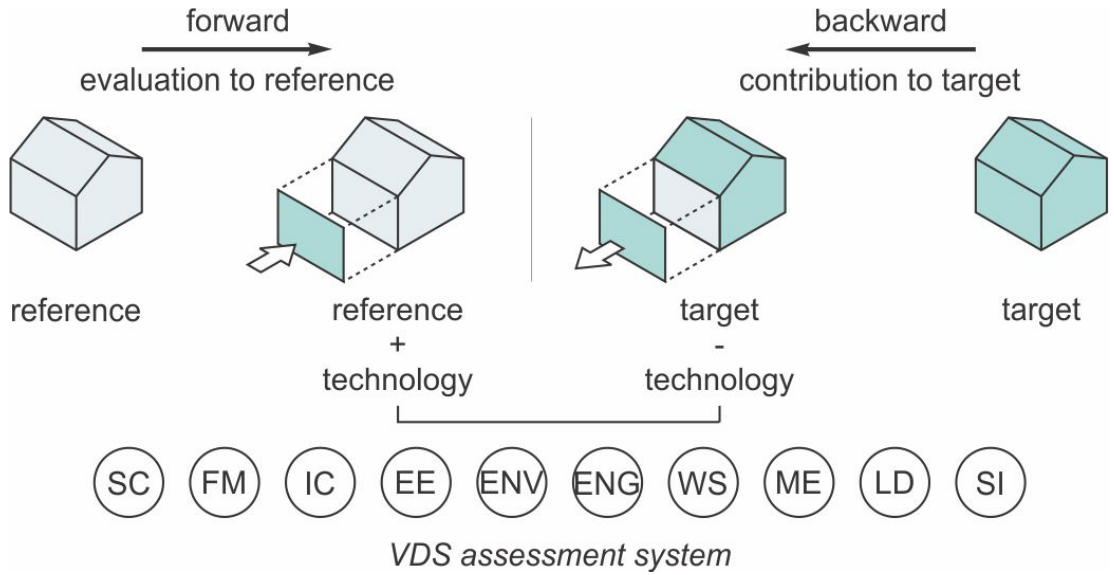
How to assess the green building performance against local reference building?

Forward step evaluation of performance improvement ***potential to reference building***

Backward step evaluation of performance improvement ***contribution to target building***

Assessment method
-> Simulation

Assessment tools
-> EnergyPlus
-> energy use
-> water use
-> thermal comfort
-> material use…
-> CONTAM
-> ventilation
-> pollutant level…



VDS assessment system

Building Performance Assessment
assessment approach

Performance improvement potential (P_i)

$$P_i = (E_{ref} - E_{ref+i})/E_{ref}$$

E_{ref} – performance effects (energy use, water use or thermal comfort…) of reference building;
E_{ref+i} – performance effects (energy use, water use or thermal comfort…) of building with technology *i*;

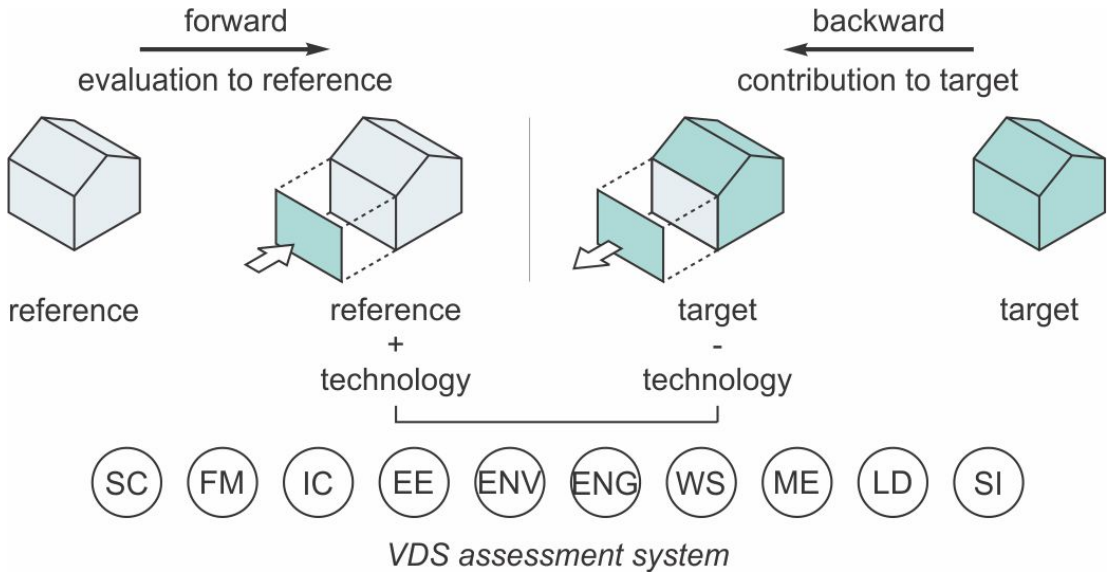
Performance improvement contribution (α_i)

$$\alpha_i = (P_{\Sigma} - P_{\Sigma-i})/P_i$$

Scaling factor (β_i)

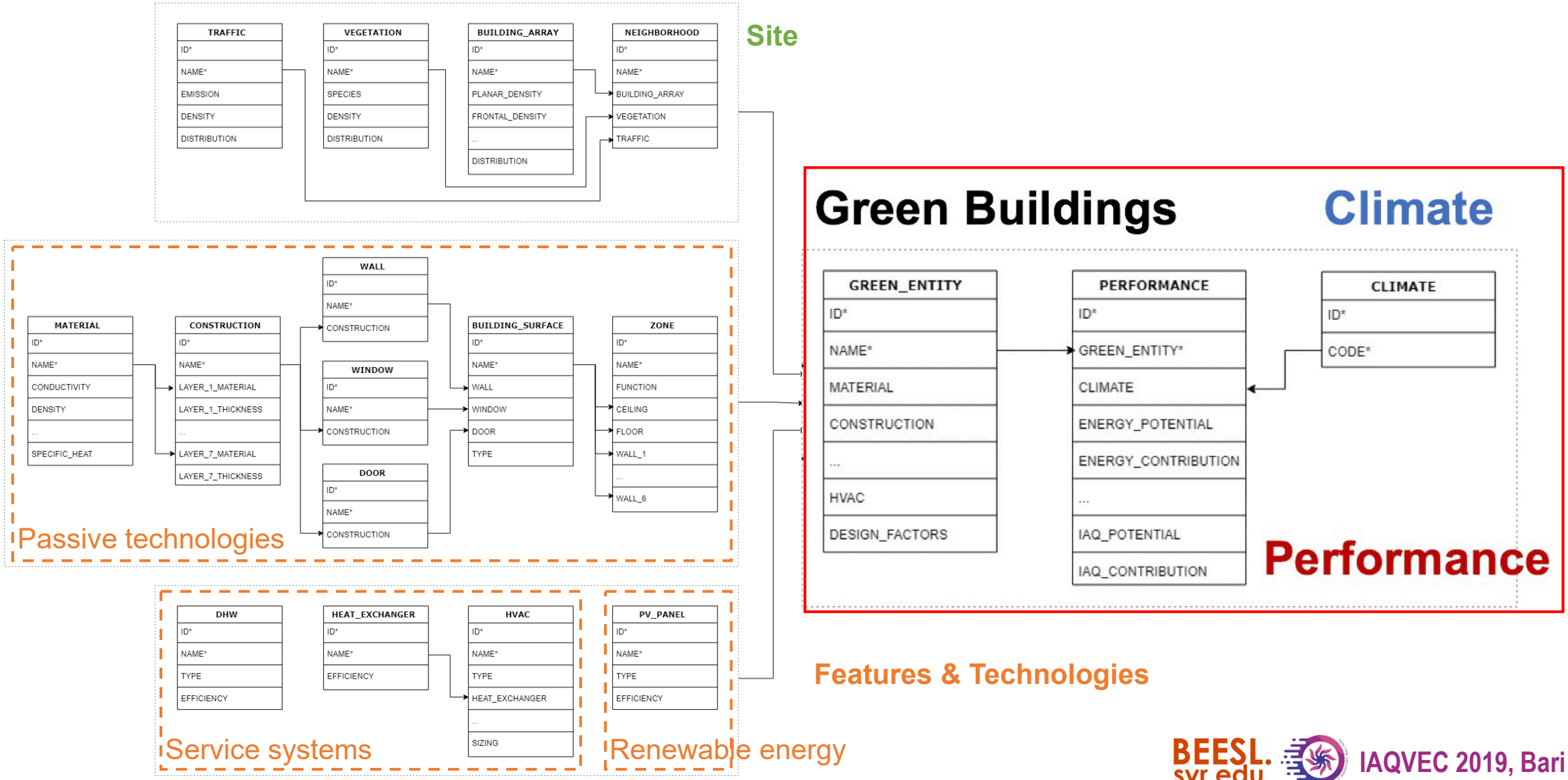
$$\beta_i = P_i'/P_i$$

P_i' – performance potential of technology *i* in different conditions;



VDS assessment system

Building Performance Assessment
database construction



Case study information

Building type:

Single-family house (223.07m^2 conditioned area)

Location:

New York City (climate zone: 4A)

Miami (climate zone: 2A)

Local reference building:

A two-story house with pitched roof and unconditioned attic (Building America Protocols from NREL)

GBTs used in case study:

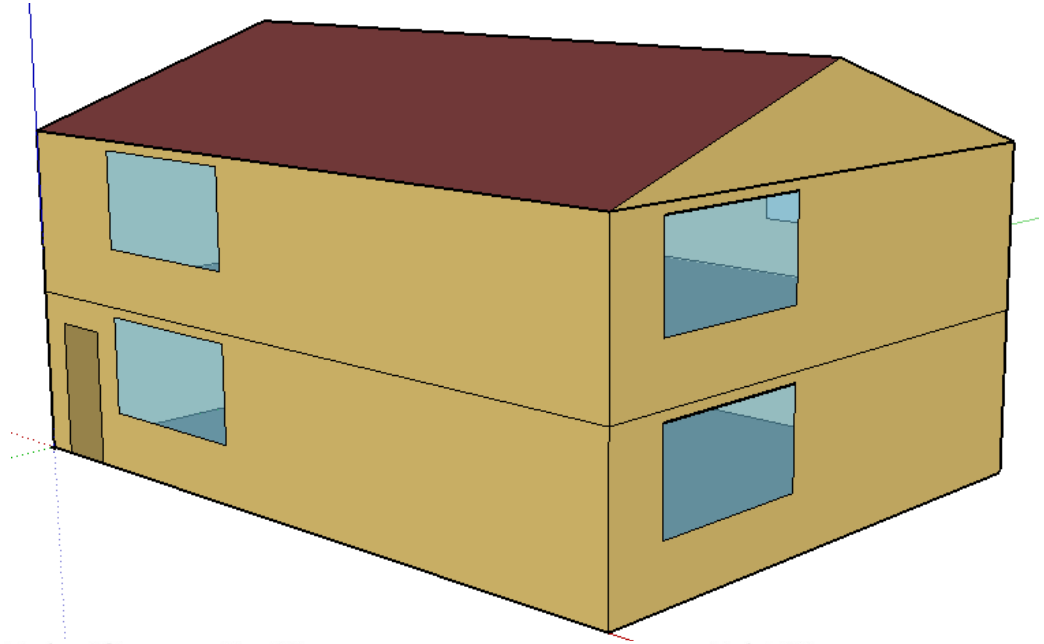
- highly-insulation exterior wall
- controlled shading system
- air-tight wall assembly

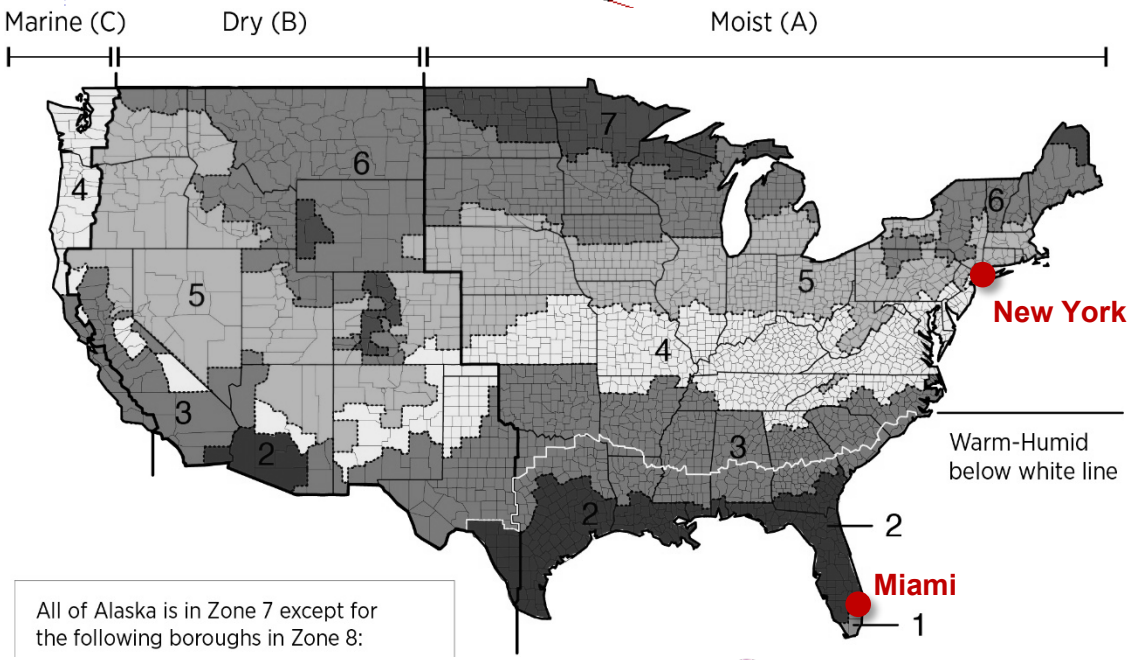
Performance aspect:

Energy consumption (heating & cooling)

Assessment tool:

EnergyPlus





E. Wilson, C.E. Metzger, S. Horowitz, R. Hendron, 2014 Building America House Simulation Protocols, Natl. Renew. Energy Lab. (2014).

Case study
results

Energy use of different cases using different GBTs

Study case	*Climate Zone*[1]	*Energy use [kWh/m²]*	*Ref*							
New York City, NY	4A	Annual	55.1	51.7	54.3	45.6	51.0	42.3	44.9	41.7
Miami, FL	2A	Annual	26.6	25.7	26.5	24.3	25.6	23.4	24.2	23.3

[1] Climate zone defined in ASHARE 169.

- highly-insulation exterior wall
- controlled shading system
- air-tight wall assembly

Performance potential (P_i) and contribution (α_i) for different GBTs in each case

Study case	*GBT*	P_i	α_i[1]			
New York City	(High-insulated wall)	0.061	/	0.98	0.98	0.96
	(Controlled shading)	0.013	0.92	/	0.99	0.92
	(Air-tight wall)	0.172	0.99	1.00	/	0.99
Miami	(High-insulated wall)	0.034	/	0.99	0.96	0.95
	(Controlled shading)	0.006	0.93	/	0.95	0.89
	(Air-tight wall)	0.086	0.98	1.00	/	0.98

[1] The performance contribution here is the contribution of the studied technology to the combination with different technologies.

- Air-tight wall has highest performance improvement potential in both NYC and Miami, while high-insulated wall and shading system have lower potential.
- Same GBT performs differently in different climate zones.
- The studied three GBTs don't affect each others' performance a lot since the coefficient (α_i) when a technology working with another technology is very close to 1 (0.89-1.00).

Conclusions & Prospects

1. Green building database based on building features and technologies is essential for module-based green building design, but is still scarce;

2. Performance assessment coefficients are suitable for the evaluation of performance improvement potential and contribution, as well as synergistic effect;

3. The database covers multiple performance aspects and can work in different climate zones;

4. More diverse building cases should be added to the database.

Thank you!

Questions & Comments

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